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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY

OF LONDON.

SECOND SERIES.

VOLUME V.

PART THE FIRST.

Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant.

Novum Organum, Præfatio.

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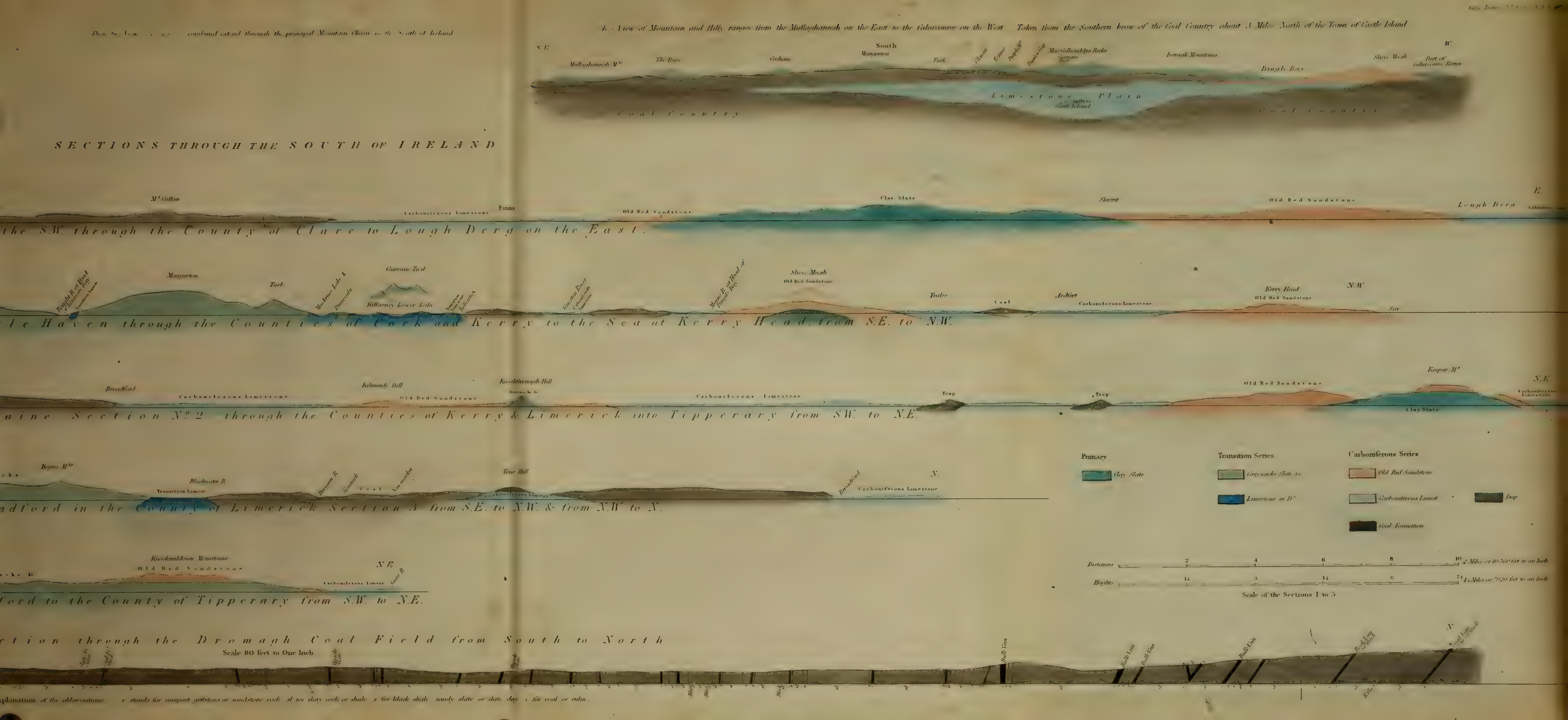
South
Bogra Mountains
Mangerton
Mac Gillicuddy's Reeks
Coal Country
SECTIONS THROUGH THE SOUTH OF IRELAND
No. 1. Section from the Sea at Loop Head on the S.W. through the County of Clare to Lough Derg
Carboniferous Limestone
No. 2. Section from the Sea at Castle Haven through the Counties of Cork and Kerr
Killarney Lower Lake
No. 3. Section from the River Maine Section No. 2 through the Counties of Kerry &
Carboniferous Limestone
Old Red Sandstone
Coal
Kilmeady Hill
No. 4. Section from the Sea at Courtmacsherry Bay through the County of Cork to Broadford in the County of Limerick Section 3 from S.E. to N
Bandon River
Greywacke
Macroom
Blackwater R.
No. 5. Section from the Sea at the entrance into Cork Harbour through parts of Cork and Waterford to the County of Tipperary from S.W. to N.E.
Knockmeledown Mountains
Old Red Sandstone
Carboniferous Limestone
No. 6 Section through the Dromagh Coal Field from So
Scale 80 feet to One Inch
Diluvial Gravel
Line of Adit Level
Explanation of the abbreviations


SECTIONS THROUGH THE SOUTH OF IRELAND
A View of Mountain and Hilly ranges from the Mullaghaneesh on the East to the Cahirconree on the West Taken from the Southern brow of the Coal Country about 3 Miles North of the Town of Castle Island
South
Mangerton
Torc
Dingle Bay
Iveragh Mountains
Limestone Plain
Castle Island
Coal Country
Coal Country
Mt Callan
Ennis
Carboniferous Limestone
Old Red Sandstone
Clay Slate
Skerrif
Old Red Sandstone
Lough Derg
the S.W. through the County of Clare to Lough Derg on the East.
Mangerton
Tork
Carrane Tual
Killarney Lower Lake
Sliev Mish
Old Red Sandstone
Tralee
Coal
Ardfert
Carboniferous Limestone
Kerry Head
Old Red Sandstone
N.W.
Sea
le Haven through the Counties of Cork and Kerry to the Sea at Kerry Head, from S.E. to N.W.
Carboniferous Limestone
Old Red Sandstone
Knockfeerinagh Hill
Carboniferous Limestone
Trap
Trap
Old Red Sandstone
Keeper Mt
N.E.
Clay Slate
aine Section No 2 through the Counties of Kerry & Limerick into Tipperary from SW. to N.E.
Primary
Clay Slate
Transition Series
Greywacke Slate &c
Limestone in Do
Carboniferous Series
Old Red Sandstone
Carboniferous Limest
Trap
Coal Formation
Blackwater R
Transition Limest
Coal
Tour Hill
Carboniferous Limestone
N.
adford in the County of Limerick Section 3 from S.E. to N.W. & from N.W. to N.
Distances
Heights
Scale of the Sections 1 to 5
Knockmeldown Mountains
Old Red Sandstone
N.E.
Carboniferous Limest
ford to the County of Tipperary from S.W. to N.E.
ction through the Dromagh Coal Field from South to North
Scale 80 feet to One Inch
N
planation of the abbreviations r stands for compact gritstone or sandstone rock sl for slaty rock or shale s for black shale sandy slate or slate clay c for coal or culm.

GEOLOGICAL MAP

of the

SOUTH OF IRELAND

BY

T Weaver Esqr FGS FRS. MRIA &c.

GALWAY BAY

North Sound

South Islands of Aran

DINGLE BAY

KENMARE BAY

BANTRY BAY

MOUTH of the SHANNON

Loop Head

Ballybunnion

Ballyheige Bay

Tralee Bay

Brandon Bay

Dingle

Valentia

Ballynskelligs Bay

Cualee Bay

Ballydonaghan Bay

Dunmanus Bay

Mizen Hd

Cape Clear

Galway

New Harbour

Athenry

Loughrea

Portumna

Lough Derg or R Shannon

Limerick

Tipperary

Cashel

Clonmel

Waterford

Dungarvan

Youghall

Cork

Kinsale

Mallow

Fermoy

Rathcormack

Dungarvan Harb

Youghal Harb

Kinsale Harb

Ballycotton Bay

Ballycroneen Bay

Roaring Water Bay

Baltimore Harb

Crookhaven

Skull

Bantry

Glengariff

Kenmare

Killarney

Tarbert

Kilrush

Ennis

Scale

English Miles

Primary Rocks

- Granite
- Mica Slate
- Clayslate

Transition Series

- Greywacke & Slate &c
- Limestone in Ir.

Carboniferous Series

- Old Red Sandstone
- Carboniferous Limestone
- Coal Formation
- Trap

GEOLOGICAL MAP

IRELAND

Tracts in which prevail

- 1 Granite
- 2 Mica slate
- 3 Clay slate
- 4 Greywacke & Slate
- 5 Old Red Sandstone
- 6 Carboniferous Limestone
- 7 Coal Formation
- 8 New Red Sandstone, Lias Green Sand & Chalk
- Trap overlying

M Towns are marked thus -

1.—*On the Geological Relations of the South of Ireland.*

By THOMAS WEAVER, Esq., F.G.S., F.R.S., M.R.I.A., &c., &c.

[Read June 4, 1830, and November 18, 1835.*]

CONTENTS.

Introduction.—Form of the Surface ..... §§. 1 to 5.
Geological Relations, and Distribution of the Subject ..... §. 6.

I.—*Transition Series.*

In Kerry, Cork, and Waterford; disposition, characters, structure, &c..... §§. 7 to 33.
Organic remains in the slate,..§§. 13, 19, 24, 26, 30.
Ditto in the limestone.....§§. 21 to 33.

Metalliferous Relations:..... §§. 34 to 46.
In the Greywacke and Slate districts §§. 34 to 41.
In the Transition Limestone ..... §§. 42 to 46.

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* It may be useful to point out in what particulars the present memoir differs from its predecessor, which was read June 4, 1830, reference being had to the Table of contents in the Memoir. The delay in finally preparing the paper has arisen from the Author's stay in Mexico and the United States from 1831 to 1834.

In §§. 1 to 6, the Introductory part and general distribution of the subject have been remodelled in some respects.

In §§. 7 to 20, the disposition, mineral characters, and organic remains of the greywacke and slate series stand nearly as before.

In §§. 21 to 33, the details of the disposition, characters, and organic remains of the transition limestone are new for the greater part.

In §§. 34 to 46, the metalliferous relations of the transition tract are much condensed, but in other respects as before.

In §§. 47 to 68, the detailed disposition, characters, and organic remains of the South Munster carboniferous series are almost entirely new.

In §§. 69 to 75, the same may be said of the North Munster carboniferous series, with the exception of the "coal formation" (§§. 71 to 75.), which stands nearly as before.

In §§. 76 to 83, the metalliferous relations of the carboniferous series are mostly new; and partly also §. 84, on segregated metallic deposits in general.

In §§. 85 to 89, the notices of Diluvial Action have been amplified to a certain extent, and rendered more general with respect to Ireland.

June 8, 1835. T. Weaver.

II.—*Carboniferous Series.*

1. In South Munster: viz. in Cork, Limerick, and Kerry; disposition, characters, and structure .. §§. 47 to 68.
Old red Sandstone, §§. 47 to 50.
Carboniferous Limestone, extending in part into Waterford, §§. 51 to 57.
Organic Remains, §. 57. 60.
Coal formation, §§. 58 to 68.
Organic Remains, §. 66.

2. In North Munster: viz. in Clare, extending in part into Galway; disposition, characters, and structure..... §§. 69 to 75.
Old red Sandstone, §. 69.
Carboniferous Limestone. §. 70.
Organic Remains, §. 70.
Coal formation, §§. 71 to 75.
(Note to §. 75, on the carboniferous series of the United States of North America.)

Metalliferous Relations: ..... §§. 76 to 83.
In the old red Sandstone, §. 76.
In the carboniferous Limestone, §§. 77. to 82.
In the Coal formation, §. 83.

General observation on segregated Metallic Deposits..... §. 84.

III.—*Notices of Diluvial Action*..... §§. 85 to 89.
In Kerry, §. 87; in Cork, Limerick, and Tipperary, §. 87; in Galway, §. 88; in Ireland generally, §. 89.

Introduction.—Form of the Surface.

(1.) IN the following communication I propose to give a sketch of the mineral constitution of the South of Ireland, including the county of Clare, and extending to the Bay of Galway. Connected with the description which I formerly gave of the Eastern portion of the Island*, the two memoirs will embrace about two thirds of the area comprised in its surface. In this, as in the former account, I shall confine myself to the more striking geological phenomena offered by the tracts described; presenting occasional details in illustration, but avoiding all theoretical speculation.

(2.) The annexed Map (see Plate II.), with the sections drawn through different portions of the tract (see Plate I. figs. 1 to 5.), and the general views of

* Geological Transactions, First Series, vol. v. p. 117 *et seq.*, pl. 6 to 15 inclusive.

the principal chain (see Sketches (*a*) and (*b*) in Plate I.), may serve to illustrate the general forms, structure, and connection of the mountain and hilly ranges with each other. In determining the geographical limits of the formations I have endeavoured to be exact*.

(3.) The Southern and greater portion of our field of inquiry, is composed of a transition tract; its northern boundary being formed, both in the eastern and western quarters, by carboniferous limestone associated, more or less, with the old red sandstone; while in the central part of the border, a coal country is found directly conjoining with the transition series. The old red sandstone both on the east and west, as well as in the northern portion of the field, attains to considerable elevation, passing in its descent beneath the more level surface of the carboniferous limestone; and the limestone here, as in other parts of Ireland, is surmounted by an elevated and extensive tract of coal measures.

---

* See the annexed Geological Map of the South of Ireland (Plate II.). In this Map I have corrected a few particulars in the south-western extremity of my former Map of the East of Ireland. Both are drawn on the same scale.

That the geological inquirer may more readily seize the connection between the East and South as well as with the North and West of Ireland, I have added a small skeleton map as an Index to the geology of the whole island (See Plate II.). In this the principal formations are distributed in groups under the heads of the granite, mica-slate, clay-slate, greywacke and slate tracts, in which these rocks respectively predominate; but greater detail is given to the carboniferous series, as its members generally appear in a distinct order of succession in the physical structure of Ireland. Then follow the new red sandstone, lias, greensand, and chalk, in one group, succeeded by the overlying trap as the last link of the chain, other formations later than the chalk appearing to be wholly wanting in Ireland.

With respect to the North of Ireland, I have availed myself in these outlines, in aid of my own local knowledge, of the excellent memoir on the North-East of Ireland by Dr. Berger, the Rev. W. D. Conybeare, and Professor Buckland[1]; and of the valuable Reports on the coal tracts of Connaught and Ulster by Mr. Griffith[2], to which works it may be sufficient to refer for the requisite details. All that seems necessary on the present occasion is to indicate the prevailing formations in the primary tracts of the West of Ulster and Connaught. In both of these the chief constituents are a base of granite, or syenitic granite, supporting mica-slate and quartz-rock, with primary limestone, greenstone, hornblende-rock, hornblende-slate, and clay-slate. In Galway white limestone occurs in the mica-slate both in its simple form and intermingled with serpentine, in the latter case constituting a beautiful green marble. And in Donegal, in particular, the white limestone approaches to the character of statuary marble, apparently suited to the purposes of the sculptor.

The geographical boundaries of the several geological groups will be readily apprehended by comparing the skeleton map with a common Map of Ireland[3].

---

[1] Geol. Trans., First Series, vol. iii. p. 121 *et seq.*
[2] Geological and Mining Reports of the Connaught and Ulster coal districts.
[3] The Public look with expectation to Mr. Griffith's promised Geological Map of Ireland.

(4.) The surface of the transition district consists chiefly of chains of mountains and hills, having generally a direction from W. to E.; and the principal, rising in Iveragh, south of Dingle bay, in the county of Kerry, attains its greatest elevation in Mac-Gillicuddy's Reeks, thence extending eastward through the county of Cork between the rivers Lee and Blackwater*. The less elevated ranges being nearly parallel to this main chain and to each other, longitudinal valleys are inclosed between them, the course of which is indicated by the principal streams; but as sinuous valleys, dells, and defiles traverse the chains, the region presents on the whole a considerably diversified aspect.

(5.) All the elevations given in the following List marked (N.) were ascertained by the late Mr. Alexander Nimmo†; those derived from the Trigonometrical Survey of Ireland, marked (T.), I owe to the urbanity of Colonel Colby, R. E., by whose directions they were furnished to me by Captain Portlock, R. E.

	Above level of sea.
On the north side of Dingle Bay:	
The Cahir-conrée and Slieve Meesh range is in the chief points	(N.) 2200 feet.
But Bartrigoun, the highest point, is according to the Trigon. Survey..	(T.) 2784
While Brandon mountain, standing out on the N. and facing the Atlantic, is, according to the Trigonometrical Survey	(T.) 3120
On the south side of Dingle Bay, in the Iveragh mountains:	
Knochadubber, facing the Bay.....	(N.) 2000
Drung, do.	(N.) 1996
Bennettee, in the interior	(N.) 1262
Knockalubrid, do.....	(N.) 1556
Cullee, on the east.....	(N.) 2000
Knockalin, on the south.....	(N.) 2150
Facing the north side of Kenmare Bay:	
In the Dunkerrin mountains the highest points vary from 1800 to	(N.) 2000
The south of the Bay:	
The chief mountains rise, according to Mr. Nimmo, to a nearly equal height‡	
In Mac-Gillicuddy's Reeks, extending toward the Lakes of Killarney:	
Gurrane Tual, which is the most elevated point, being also the highest land in Ireland, is according to Mr. Kirwan.....	(K.) 3405
——————————— Mr. A. Nimmo	(N.) 3410
——————————— the Trigonometrical Survey	(T.) 3404

* For a view of this Chain, see Plate I. Sketches (*a*) and (*b*).

† See Reports to Parliament on the Bogs of Ireland.

‡ Smith in his Natural and Civil History of Kerry, p. 355, states that in the year 1756, at the entrance of Kenmare river, the magnetic variation was 17° W. At Ross Island, in the lower lake of Killarney, I ascertained the magnetic variation in 1829 to be 28° 45′ W.

	Above level of sea.
Purple mountain	(N.) 2280
Tomies mountain	(N.) 2150
Glenaa	(N.) 2090
Turk mountain	(N.) 1900
Mangerton, according to Mr. Kirwan	(K.) 2693
——— Mr. A. Nimmo	(N.) 2550
Beyond the Lakes:	
Crohane mountain	(N.) 2175
Paps mountains	(N.) 2280
Cahirbarna	(N.) 2090
Gortavehy, highest point	(N.) 1815
——— lower	(N.) 1500
Knock Claragh	(N.) 1385
Muskerry, or Musheragh	(N.) 1990

Thenceforward, through the Bogra and Neagles mountains, with the Watergrass hills, spreading between the rivers Lee and Blackwater, and extending to the eastward, this principal range declines gradually in elevation. In the Neagles range, Knockbena Skeagh is, according to the Trigonometrical Survey, 1388 feet above the sea.

On the south of this main chain, and beyond the river Lee, high land still prevails, yet forming lower ranges, the surface of which is undulated from north to south; but in the disposition of these ranges a similar declension in altitude from west to east is observable, the principal elevations being found adjacent to the west and south coast. Hungry Hill, on the north side of Bantry Bay, is, according to the Trigonometrical Survey, 2,249 feet above the level of the sea.

North of the parallel of the Lakes of Killarney and the river Blackwater, the coal country of the counties of Kerry, Cork, and Limerick presents more equally flowing outlines in its surface, which may be compared to a series of complex undulations upon a large scale, in which the higher portions vary between 1000 and 700 feet, and the lower between 500 and 300 feet, above the level of the sea; but Tour mountain, situated in this tract north-west of Newmarket, is according to the Trigonometrical Survey elevated 1329 feet above that level.

The boggy district between Killarney and Millstreet is, in the central parts, between 500 and 400 feet, and at the eastern and western extremities 300 feet; while the lower lake at Killarney is 50 feet, above the level of the sea, and in its deepest part 190 feet below that level, its extreme depth from the surface being 240 feet.

Proceeding more to the north, the following heights have been determined by the Trigonometrical Survey of Ireland:

	Above level of sea.
In the Waterford mountains, Monavoullagh (highest point)	2590 feet.
In the Knockanafrun, part of the same range.....	2469
In the Gaultees range, Gaultymore	3000
In the Tipperary mountains, the Keeper.....	2265
——————————— the Devil's Bit	1572
In the Limestone Plain of Limerick, Knock Dirk	477
——————————— Knockfeernagh.....	937
In the hills of Clare, Craig	1715
——————————— Knockaness	1305
——————————— Callan.....	1297
And in the East of the Island, Mount Leinster in the county of Carlow..	2604

Geological Relations, and Distribution of the Subject.

(6.) In the general relations of the transition tract of the South of Ireland great analogy is found to subsist. To prevent repetition, I propose to take a few examples as types, selecting them in the eastern and western extremities of the tract, in which the greater diversity is observable; namely, in the county of Kerry, the adjacent portions of Cork, and the south coast of the county of Waterford, adding incidentally such further observations as may conduce to the fuller understanding of the whole of the transition field, and which may more particularly appear when I proceed to speak of its metalliferous relations. The carboniferous series of Munster, extending from the old red sandstone upward to the coal formation inclusive, may be conveniently considered under two heads: 1. The South Munster, embracing portions of the counties of Cork, Limerick, and Kerry; and 2. The North Munster, appearing in the county of Clare, and extending thence in part into the county of Galway. But though separated at the surface by the Shannon, these two fields are assuredly connected with each other beneath that river.

I. Transition Series.

In Kerry, Cork, and Waterford.

(7.) The county of Kerry comprises rocks of great variety of character, which, though relatively of unequal continuity and distribution, are yet so perfectly inosculated as to constitute a persistent series. Their general range is E. and W., subject to inflections from that line. The dip is interchangeably N. or S., the angle of inclination fluctuating from the vertical to the horizontal nearly. From this arrangement arises a succession of ridges and

troughs; the ridges containing a central axis of vertical beds, from which the lateral strata diminish in elevation on each side, while in the troughs are inclosed other beds which gradually approach to the vertical position in the centre of the trough. These variations in the line of range and dip occupy spaces of greater or less extent; but independently of this general disposition, involutions and contortions of the strata are also occasionally observable.

(8.) Though the rocks of this portion of Ireland present great differences in aspect and structure, the principal masses may, in a great measure, be referred to compounds of quartz and slate variously intermingled and associated. Limestone, another principal mass, also offers considerable varieties, and upon its confines with other rocks, it is found more or less charged with a portion of their ingredients. In generalizing the view, the country may be considered as chiefly composed of greywacke, slate, and limestone.

To be more particular, we may designate the whole series as consisting of simple and compound rocks. The simple rocks are clay-slate, quartz-rock, hornstone, lydian-stone, and limestone.

The *clay-slate* is bluish, greenish, seldomer blackish grey, often brownish, reddish or purplish, and glimmering, or glistening, more rarely wholly dull. In some quarters the slate appears as a quartzy clay-slate, and in others as a shivery shale.

Quartz-rock, generally of various shades of greyish white, more or less compact and fine splintery, or granular; sometimes also reddish, bluish, or greenish, when coloured by an intimate mixture of the substance of clay-slate.

Hornstone, or *chert*, yellowish, reddish, or greyish white, compact, even, and fine splintery.

Lydian-stone of its usual aspect, but sometimes passing into flinty slate.

Limestone of various shades, from dark to light bluish grey, also pale grey with streaks of reddish and yellowish white, more rarely black; and in structure varying from compact to sublamellar.

The limestone in some quarters forms frequent alternations with the lydian-stone, hornstone, and quartz-rock, involving in its substance also shapeless portions of those rocks, for example—in several of the beautiful isles of the Lower Lake at Killarney, in some of which, as in Ross Island, beds of clay-slate are likewise interposed in the series; and in Muckruss peninsula, both on its northern and southern shores, the limestone may be observed alternating with slate and greywacke slate, where it borders upon rocks of that description. In other quarters the limestone is less interrupted, appearing in purer beds which afford excellent lime, *e. g.* in the Drishane quarries near Millstreet, or being deteriorated by a commixture of siliceous particles become less tractable, *e. g.* in the limestone of the Kenmare district.

(9.) The compound rocks may be enumerated under the following heads: clay-slate conglomerate, quartz conglomerate, greywacke, and greywacke slate, sandstone conglomerate, sandstone, and sandstone slate, greenstone, and hornstone porphyry. Of these the greywacke, greywacke slate, sandstone, and sandstone slate compose the predominant rocks, the coarse conglomerates

being of more casual distribution, for example, the sandstone conglomerate in Dunloe Pass west of the lower lake of Killarney. Greenstone*, and hornstone porphyry, are more local occurrences: the former may be observed in Begnish Isle adjacent to Valentia Island, and the latter within the range of Mac-Gillicuddy's Reeks. In the general series of these rocks, the purer clay-slate, fit for roofing, occurs in beds incidentally distributed and of variable thickness, yet bearing but a small proportion to the entire mass, *e. g.* the indifferent, bluish and greenish slates procured from Mangerton and Glen Flesk, and the reddish brown from Dunloe Pass; but in the island of Valentia an excellent roofing-slate is obtained, which may vie with any for firmness and durability, possessing also an agreeable subdued purplish colour. Beds of quartz-rock, hornstone, and lydian-stone, also occur incidentally in the general, compound series; but the last-named substance is comparatively very rare in the greywacke and slate country, its more usual representative being there a flinty slate.

(10.) The common character of the clay-slate conglomerate and greywacke is that of a base of slate or quartzy slate, enveloping rounded and angular fragments of quartz and slate (sometimes in the form of considerable pebbles) but very rarely inclosing small portions of felspar also. The greywacke slate is the same rock, of finer grain and fissile structure. Numerous scales of silvery mica enter also more or less largely into the composition of these rocks, as wellas occasionally into that of the purer clay-slates.

A great variety of these substances, together with some sandstone conglomerate, may be observed on the coast adjacent to Smerwick harbour, beds of clay-slate also appearing in the association. The beds in this quarter dip 65° to 80° S.; but in traversing the peninsula southward, to the confines of Dingle bay, they gradually acquire a vertical position, then a northerly inclination, and re-assuming a vertical position, they again acquire the southerly dip. In the Cahir-conrée chain a disposition somewhat similar may be observed: thus in the northern face of the eastern quarter, where the Slieve-Meesh range may be said to commence and in which old red sandstone prevails, strata of sandstone appear, including some of conglomerate dipping 50° to 45° to the north; but on penetrating into the mountains on the south by the valley which runs about two miles and a half in that direction, its mouth fronting Kilgobbin, these sandstone strata may be observed gradually merging into varieties of greywacke and greywacke slate, associated with red, brown and greenish coloured clay-slate, and with occasional beds of similarly coloured sandstone;

* Namely, true greenstone, a compact, or subcrystalline compound of felspar and hornblende. In Kerry, and generally in the South of Ireland, the rock popularly called *greenstone* is a greywacke, or sandstone, of a greenish hue, and the *brownstone* of the country consists of the same kind of rock of a brownish or reddish colour.

the series progressively rising at a higher angle until they become vertical, while still further south a successive interchange of dip takes place in these beds, analogous to that already noticed as occurring throughout the transition field. To the eastward, this series is overlaid by the old red sandstone of Slieve Meesh, which forms a flatly arched inflection from north to south; but at its eastern foot the greywacke re-appears adjacent to the river Maine.

In various parts of the country, the basis of the fine-grained greywacke is found occasionally to effervesce partially with acids, though no calcareous matter be obvious to the eye. Such, however, does casually appear when approaching the limestone, and sometimes even at the distance of one or more miles.

In the quartz conglomerate, the basis being quartz, the ingredients are analogous to those of the clay-slate conglomerate. In the sandstone conglomerate also the larger included portions are essentially composed of quartz and slate, the former being usually white or grey, but sometimes tinged reddish or greenish; while the basis consists of compact, granular or sandy quartz, numerous scales of silvery mica, and an occasional diffusion of white earth, like that which proceeds from decomposed felspar. From this coarse compound, a gradual transition may be traced to the finer-grained sandstone and sandstone of a slaty structure, and thence, by the greater consolidation of quartzose matter, into quartz-rock itself.

This gradation may be seen exemplified in the entrance of Dunloe Pass, where all these rocks possess more or less a reddish or brownish tint, agreeing in that respect with the neighbouring clay-slate. Those which are first encountered dip at an angle of 60° to the S., which angle they retain until we find a bed of the sandstone conglomerate in juxta-position with a reddish roofing-slate, the latter dipping 63° S. at the point of contact, but at a distance from the conglomerate (being about 70 yards thick) gradually assuming the vertical position. Further S. the beds decline to as low angles as 35° and 30°,—then undulate on a small scale for some distance, and subsequently resume the southerly dip at a higher angle. But from Dunloe Pass to Kenmare Bay, though the more general disposition of the strata be to the S., an occasional change of dip toward the N. is also observable, vertical strata in such cases commonly intervening.

(11.) I may here remark that in the whole extent of the greywacke and slate country, contemporaneous veins of quartz are more or less common to the several members of that series, most usually traversing them in the line of the dip.

(12.) It will be seen in the Map, that the distribution of the limestone is very unequal in the general expanse of the transition field, the interposed masses not assuming a regular form; yet the strata are always parallel to those of the rocks with which the limestone is in contact; and within the limestone ranges, the stratification is occasionally subject to inflections and variations in the line of dip, as well as to contortions, analogous to those within the grey-

wacke and slate tracts, the scale of these changes of curvature also varying. An example of this kind may be seen, to the best advantage, on the western side of the Isle of Innisfallen, in the Lower Lake of Killarney, when the lake is at its lowest level, as well as in some of the adjacent islands.

(13.) In the series of the greywacke, sandstone, and slate country now described, I have to notice the organic remains which have occurred to me. Those found in the transition limestone will be afterwards considered under that head. The only quarter in Kerry, in which I discovered numerous organic remains in the greywacke and slaty rocks, is situated on the western coast near Ferriter's Cove, adjoining Smerwick harbour. They are there distributed in slate and fine-grained greywacke, which occasionally effervesce with acids, though no carbonate of lime be perceptible to the eye; the petrifactions themselves appearing either as mere impressions, or as casts of the interior, composed of the substance of the rock, namely, of slaty matter, fine-grained greywacke, &c.

Among these I observed the *Calymene Blumenbachii* (Brongniart, pl. 1. fig. 1.) †‡[1], and apparently also the *Asaphus caudatus* (Brongniart, pl. 2. fig. 4.) †‡, an Orthoceras, Euomphalus, two

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[1] The mark † implies that the species occurs in Great Britain or other countries, in the *Transition System*.
The mark * that the species occurs in Ireland,
The mark ‡ ——————— Great Britain or other countries, } in the *Carboniferous System*.
See further hereon in §§. 33 and 57.

In Europe the occurrence of the *Calymene Blumenbachii* and *Asaphus caudatus* may be exemplified in the following manner:

	Transition.	*Carboniferous.*
Calymene Blumenbachii ..	† Ferriter's Cove; Dudley; Ledbury; Tortworth; Newton Bushel; Eifel; Scania; Ostrogothia, &c.	‡ Gottland, A.
Asaphus caudatus	† Ferriter's Cove; Bonmahon coast, county of Waterford; Dudley; Ledbury; Tortworth.	‡ Beadnell, Northumberland (See Prof. Buckland's excellent Bridgewater Treatise); Coalbrook Dale (Mr. Prestwich MS.) Gottland, A.

The division of the Gottland limestone marked A, is referred by Mr. Hisinger to the carboniferous epoch, but some doubt seems to attach to the correctness of that reference. (See Mr. De la Beche's Geological Manual, 3rd edition. By some mischance the *Asaphus caudatus* is omitted in Mr. De la Beche's list of transition fossils.)

On the other hand, in the United States of North America, the *Calymene Blumenbachii* occurs also both in the transition and carboniferous systems, but the *Asaphus caudatus* has not yet been met with in the latter: e. g.

	Transition.	*Carboniferous.*
Calymene Blumenbachii..	† Glenn's Falls, upon the Hudson River, Trenton Falls, upon the Mohawk River,—both in the State of New York; Cincinnati; Louisville on the Ohio.	‡ Black Rock on Niagara, (see Annals of Lyceum of New York, vol. i. part 1.
Asaphus caudatus	† Glenn's Falls upon the Hudson; Cincinnati; Louisville on the Ohio.	

(See Dr. Harlan in the 1st vol. of the Transactions of the Geological Society of Pennsylvania;

turbinated shells, one being carinated, the other striated, and a Natica; the *Producta depressa* (Sow. Min. Con. t. 459. fig. 3.) †*‡, and other Productæ; the *Spirifera radiata* (*olim lineata*, Sow. t. 493. fig. 1. 2.), †‡, and other Spiriferæ; the *Terebratula prisca* of Schlotheim (Tab. 17. fig. 2.)[1] considered as identical with *Terebratula affinis* of Sowerby (t. 324. fig. 2.)†*‡, and other Terebratulæ, as well as a *Pentamerus* Sow. (t. 28. 29.) †, and other bivalves, besides casts of the interior of Terebratulæ, Spiriferæ, and Productæ, generally designated by German geologists by the name of *hysterolites*; Polyparia, of the genera Cyathophyllum, Turbinolia, and Favosites; and also crinoidal remains. The *Turbinolia* appears closely to resemble the *T. celtica* of Lamouroux (Tab. 78. fig. 7.)†, also derived, it seems, from a transition tract[2].

Several of these casts so perfectly resemble both in the species of the original shell and in composition, similar casts occurring in the Tortworth transition district in Gloucestershire, which I formerly described[3], that on examining them they might be supposed to have been derived from thence. In both districts the *Turbinolia celtica* ? is common. Some of the casts are also identical with fossils figured by Sir Alexander Crichton as occurring in the transition greywacke and slate of the Duchy of Nassau[4]. In addition to these remains I have to state that the late Mr. Alexander Nimmo found in the slate, adjacent to Dunmore Head, impressions of plants, which, according to his description, would appear to be referable to Calamites.

Organic remains are also visible in the greywacke, which protrudes from beneath the old red sandstone at the eastern foot of Slieve Meesh (§ 10), forming a low ridge which crosses the river Maine, and extends some distance beyond it. On the right bank of that river, in the lands of Riversville, a quarry, which has been opened eight feet deep, exhibits beds of fine-grained greywacke, from two to six inches thick, with slight layers of slate interposed in the lower part, but alternating in the upper with beds of clay-slate and limestone, from four to six or eight inches thick, the whole dipping 12° to 15° to the E. of S. The organic exuviæ being closely entangled with the rock, are best discerned where the latter is partially decomposed, and the most common appeared referable to Productæ, Spiriferæ, Terebratulæ, Favosites, and Crinoidea.

On the eastern side of Ireland, namely, on the banks of the Oom-boy river,

and Prof. Eaton, Geological Text-Book, 2nd edition.) I collected specimens myself at Louisville and Cincinnati.

From Dr. Harlan's list it appears that numerous other species of the genera Calymene and Asaphus occur in the transition and carboniferous systems of the United States, but a clear division of them is much wanting. Many of these have not hitherto been noticed in Europe. (See Trans. of Geol. Soc. Pennsylv., vol. i. pp. 99 to 103.)

[1] Nachträge zur Petrefactenkunde.

[2] Lamouroux, Exposition methodique des Genres de Polypiers, p. 85. Paris, 1821.

[3] Geol. Trans. Second Series, vol. i. p. 326—329.

[4] Geol. Trans. Second Series, vol. ii. plate xxxiii. fig. 1, 4, 5.

which flows into Cork harbour, Mr. Nimmo informed me that Orthoceratites and other organic remains are also to be met with in the slate ; and Mr. S. Wright, of Cork, assures me that he has frequently seen small Orthoceratites in the clay-slate near the town of Cove in Cork harbour ; also Spiriferæ or Terebratulæ in the slate on the Bandon road, five miles south from Cork, but not sufficiently distinct to admit of the identification of species.

(14.) In tracing the transition rocks from Kerry into the counties of Cork and Waterford, an analogous structure and composition are everywhere perceptible, diversified, however, by numerous varieties ; one member also sometimes prevailing more than another in the series. Of this disposition the unequal bands of limestone which pervade the tract, as well as the isolated patches more locally distributed, are sufficient exemplifications. The general observation may also be made, that the conglomerated structure, and the reddish or brownish hue are more particularly developed in the greywacke and slate rocks which occur north of the parallel of the river Lee ; while in the parallel to the south of that river the same class of rocks exhibits commonly a finer structure and a light bluish or greenish grey cast ; but both parallels contain incidentally the other modifications which have been noticed.

(15.) The transition rocks on the south coast of the county of Waterford extend from the vicinity of Dungarvan toward Tramore. As they exhibit a series of considerable interest, I shall here subjoin such an account of them as may help to complete our view of the modified structure and association of the general series.

Clay-slate.—1. More or less pure, and partly glossy ; blackish, bluish, greenish, or yellowish grey ; also reddish brown or purplish. These slates contain more or less numerous scales of silvery mica disposed parallel to the laminæ. The blackish slates are partly aluminous. 2. Quartzy clay-slate containing some crystals of felspar. 3. Quartzy clay-slate containing finely disseminated hornblende, and sometimes also crystals of glassy felspar. 4. Clay-slate very firm, yet fissile, partly porphyritic.

Greywacke.—1. Slate enveloping crowded grains of quartz as large as peas, portions of the paste consisting also of green steatite. 2. Slate or quartzy slate inclosing angular and rounded grains of quartz, with small fragments of slate, and numerous scales of silvery mica, and with or without grains of felspar. 3. Greywacke slate, the same rock as the preceding, but of fine grain and slaty structure. 4. A fine-grained base, compounded of slate and quartz, containing isolated, round grains of white quartz, of the size of large peas, the rock at a distance appearing like an amygdaloid.

Quartz-rock.—1. In its simple forms. 2. Containing small globules of chlorite, and also particles of hornblende, from the partial decomposition of which it acquires an ochreous aspect. 3. Quartz-rock (sometimes graduating into hornstone, or partially into compact felspar), containing numerous reddish and yellowish white crystals of felspar, forming a handsome porphyry ; sometimes containing also particles of hornblende. 4. Quartz-rock (sometimes merging into hornstone),

in which are disseminated crystals of yellowish white felspar, and also crystals and globular portions of brownish grey vitreous quartz, and a few scales of mica. 5. A base of quartz, coloured by clay-slate, and partially also by hornblende or chlorite; a compact greenish grey, or greyish green rock, containing incidentally particles of hornblende and crystals of glassy felspar, and sometimes grains of vitreous quartz. Without attention it may be confounded with greenstone.

Hornstone.—1. In its simple forms, splintery or conchoidal. 2. Containing crystals of glassy felspar, or flesh-coloured crystals of felspar, or both conjointly, forming a handsome porphyry. The base is often of a yellowish, and sometimes of a hair-brown colour, and in the base a portion of steatite is sometimes diffused, and the rock then becomes unctuous to the touch. 3. Hornstone forming the base of the compound described under the head of Quartz-rock No. 4.

Quartz Conglomerate and Hornstone Conglomerate, coarse- and fine-grained.—A base of quartz or hornstone (or partially of compact felspar), much incorporated with steatite, and thus acquiring a saponaceous feel, and containing crystals both of dull and glassy felspar; as does also the green steatite when appearing in a distinct form, which is frequently the case. This base envelopes numerous fragments of quartz, hornstone, and hornstone porphyry, those of the two latter varying sometimes from the smallest size to that of blocks of one and two feet in diameter.

Red Conglomerate, Red Sandstone, and Red Sandy Slate.—These all contain numerous scales of silvery mica. The conglomerate and sandstone are compounded principally of rounded and angular fragments of quartz and red slate, connected by a basis of similar composition but smaller grain, or by a simple base of quartz or reddish slate. In the mixture some grains of decayed felspar may also be incidentally observed. The compound is sometimes greyish as well as reddish coloured. The ingredients in the conglomerate rarely exceed the size of cherries, but sometimes extend to that of turkey's eggs, and even a man's head, in magnitude. When the slaty basis predominates, a sandy slate is formed [1]. These beds are sometimes associated with irregular masses and beds of quartz, from an inch to one, two, and three feet wide, which bear a great quantity of beautiful, deep green chlorite.

Greenstone and Compact Felspar.—1. Compact greenstone, a base of compact felspar, coloured greenish grey by hornblende, and containing particles or crystals of hornblende, and sometimes also crystals of felspar, thus appearing as a porphyry. The felspar base acquires a white aspect by weathering. 2. Sub-crystalline greenstone, a confused intermixture of greenish grey glassy felspar with hornblende, being also spotted with blackish green hornblende. 3. Compact reddish brown or purplish felspar, partially intermingled with chlorite, or green steatite, and containing also minute crystals of glassy felspar. 4. Greenstone conglomerate, a base of greenstone, enveloping portions of greenstone, mostly of an angular form.

The sub-crystalline greenstone seldom occurs in a distinct form on this coast. The compact greenstone, which more generally prevails, exhibits a difference of character according to the state in which the hornblende enters into the composition, the greater or less prevalence of siliceous matter, and the intimate blending of chlorite. If the hornblende be unaltered, the rock is rugged and stony; if partially decomposed it is saponaceous. It is probably to this unequally affected state of the hornblende that the unequal state of aggregation in the greenstone is partly due; and that one portion consisting of comparatively loose materials is found serving as a base to numerous harder portions which are embodied in it; a difference ascribable to disturbance during the process

[1] These rocks, like analogous productions in Kerry, &c., are not to be distinguished by mere mineralogical character from varieties which occur in the old red sandstone of the carboniferous series.

of concretion. In places, the compact greenstone merges into quartz-rock, deeply coloured by chlorite.

Red Sandstone Conglomerate, and Greenstone Conglomerate.—When the red sandstone and the greenstone beds come in contact, a gradation may be traced in some places from the one rock to the other, through the medium of a conglomerate, the extreme links of the chain being the following: 1. A basis of fine-grained red sandstone, enveloping rounded and angular fragments of red conglomerate and sandstone, and of greenstone, the two former exceeding the latter in quantity. 2. A base of compact greenstone, inclosing rounded and angular fragments of greenstone, and of red sandstone, the former predominating. In both conglomerates, the included fragments occur from a small size to that of a child's head.

The crystals noticed in the preceding varieties of clayslate, quartz-rock, hornstone, greenstone, and compact felspar, appear to be of contemporaneous formation with the rock itself, possessing angles sharp and well defined.

(16.) The rocks thus described form beds intimately connected with each other by direct association, gradations, and repeated alternations, but without any specific order of succession or continuity. Their range is east and west yet subject to inflections from the line, while the dip changes from the north to the south, the beds being commonly at an angle approaching the vertical; but in the most eastern part of this coast, trending toward Tramore bay, they are inflected to a much greater extent, and partially disposed at a low angle of inclination.

Between the river Bonmahon and the bay of Ballydoan situated two miles west, there are fewer varieties of rock exhibited than occur more west and north of that bay. In the bay itself, the immediate association of the red sandstone and greenstone beds is well exemplified, in double alternation; and in the line of contact between the two rocks may be observed those graduations from the one into the other, through the medium of the compound conglomerates, which I have just described. North of these beds varieties of slate are found, alternately with greywacke, quartz-rock, hornstone, red sandstone, and conglomerate, and containing subordinate beds of greenstone, with the porphyritic varieties of the rocks which I have described. This arrangement is well exposed, in the western continuation of this coast, extending toward Dungarvan. To the eastward of the river Bonmahon the composition is analogous, with this exception, that no red conglomerate appears on that part of the coast, forming a portion of this transition series; it probably, however, occurs inland, as indications of red slate are there observable. More east upon this coast, the steatitic varieties of hornstone and conglomerate are, in particular, well displayed near Annestown, to the east of Kean Head.

(17.) Disseminated iron pyrites is not uncommon in the transition rocks of this coast, particularly in the blackish and bluish slates, which, by mutual decomposition, form sulphates of alumine

and iron, giving rise to extended exudations, which spread over the face of the cliffs in dirty brown yellow, and white streaks. It rarely occurs, however, in the red conglomerate and red sandstone. These are more especially distinguished by the diffusion of the red and yellow oxides of iron, which substances frequently occupy their interstices.

(18.) Numerous veins of quartz are found in all the rocks of the transition series on this coast, and of calcareous spar in most of them. They are, however, least frequent in the red conglomerate and red sandstone. Veins of hornstone also often traverse several of the rocks, in some places pursuing a very tortuous course. All these veins vary from a thread to four, six, or eight inches in width, and rarely exceed a breadth of one or two feet, frequently ramifying, and terminating in filaments. Many of them are wholly barren and discontinuous; but others, whether consisting simply of quartz, or of calcareous spar, or a compound of both, bear copper and lead ores, either separately or conjointly; those bearing copper ores separately being the most common. Where these ores occur, the face of the cliffs is generally stained with blue and green streaks, arising from the decomposition of the sulphurets of copper.

(19.) In one portion of this district I met with organic remains, namely, immediately eastward of the Bonmahon river, both upon the coast and inland, disposed in fine-grained greywacke and greywacke slate. In the former quarter they appear in the face of a cliff, which consists of coarse slate, the cleavage planes of which are nearly vertical; but the organic remains form a number of parallel lines, arranged in an horizontal position, thus traversing the fissile structure of the rock, and constituting so many layers, at the distance of three to six inches apart, a disposition which might give rise to some curious speculation. This deposit occupies a considerable portion of the face of the cliff upward, though in length it extends only about twelve fathoms. I must remark, however, that the organic remains are not wholly confined to these parallel lines, occurring also scattered through the mass of the rock. They here consist of three or four species of Polyparia, several bivalves, and a Turbo; but inland I found, in addition to these, the *Asaphus caudatus*, and the whole may bear a strict comparison with similar remains in Kerry, Gloucestershire, &c., *hysterolites*, or the casts of bivalves, also appearing among the number, and closely resembling those figured by Messrs. Phillips and Woods as occurring at the summit of Snowdon[1].

(20.) Generally speaking, this transition series is connected, on the north, by insensible gradations with the great body of clay-slate which prevails in that part of the county of Waterford, the whole sustaining, upon the higher lands, unconformably, extended overlying masses and caps of the old red sandstone[2],

[1] Annals of Philosophy: December 1822.

[2] The horizontal position of the old red sandstone formation in the Monavoullagh range is well marked in a drawing representing the precipice in that formation, which overhangs the Lake of Coumshenane 1100 feet in height. (See Dublin Penny Journal of Oct. 20, 1832.)

and on the flanks partial borders of the same formation, the latter supporting the carboniferous limestone in conformable position in those quarters.

(21.) Turning now our attention to the bands and isolated masses of limestone which are included in the transition tract, I may remark, that the greater part of these limestones are continuous in the mass, yet appear interlaminated or interstratified with the slaty rocks wherever exposed on their confines with the latter. A remarkable feature attending most of these bands of limestones is, that they occupy the line of valleys or dells, being flanked on each side by elevated ranges of greywacke and slaty rocks. They seem to belong to some of the oldest of the transition class, the species of organic remains which they contain being, so far as my experience extends, not many in number, and being also sparingly and partially distributed. The close researches of Mr. S. Wright in the Cork limestones lead to the same conclusion, as will fully appear in the sequel.

(22.) To the north of the road between Skibbereen and Ross is a calcareous district, extending about three miles in length and one to one and a half miles in width, consisting of isolated elliptical masses of bluish grey limestone, arranged in somewhat of an echelon order in grey clay-slate, the latter being also partly calcareous when adjoining the limestone. An analogous deposit exists also on the western side of Courtmacsherry bay; in these I observed only crinoidal remains and a few bivalves.

About three miles north of Bantry town, and adjacent to the narrow inlet from the sea, called Reenadunagan Lake, is a band of grey limestone, about one quarter of a mile wide, which has been traced upon the range some little distance to the eastward. It lies in pale bluish-grey, glossy clay-slate, arranged in strata from one to one and a half feet thick where continuous; but on its confines with the slate on the south, it is interlaminated with the latter in layers only a few inches thick, all dipping 45° to the south at the point of contact; while in receding, both north and south, the beds gradually acquire a higher inclination. The thinner layers of limestone are usually compact, and the thicker granularly foliated, the latter appearing compounded of the comminuted fragments of crinoidal remains. I did not observe any bivalve.

(23.) At the head of the bay of Kenmare is a limestone district, which extends to the east and west of the town of Kenmare, being about ten miles long, and from a half to a quarter of a mile broad, and confined to the right bank of the river Rought and the bay of Kenmare. At its western extremity, on the townland of Reens, it gradually narrows to a point on the north shore of the bay, yet extends through the adjacent islands of Cappanacus and Dunkerrin. The limestone strata appear continuous throughout, and nearly rectilinear in

their course, with a dip uniformly to the southward at angles from 75° to 80°, except on the northern side of the western extremity, where they partially dip to the north, but at the same high angle, vertical strata probably intervening. In the adjoining slate and greywacke country, both on the northern and southern sides of the limestone, analogous, corresponding variations in the dip are likewise to be observed. In this limestone, organic exuviæ are very sparingly distributed, consisting of a few bivalves with some crinoidal remains.

(24.) In the Killarney limestone district, the southern and eastern parts of Muckruss peninsula, consist of blue limestone in nearly continuous strata. North and west of the continuous band, the limestone alternates with thin layers of slate and greywacke slate, and still further north, where beds of compact, fine-grained, greywacke predominate, the beds of limestone gradually disappear. In the region of Muckruss mine, the limestone strata dip about 70° to the southward, but further south they gradually acquire as low an angle as 30°. Bivalves and fragments of Crinoidea occur in the Muckruss limestone, and in the adjacent slate and greywacke slate, but they are confined to a few species. They are incidentally met with also in the limestone of the vicinage of Killarney, being, however, rare in proportion to the greater quantity of siliceous matter in that rock. Indeed, in those parts where the calcareous repeatedly alternate with the siliceous beds, scarcely the vestige of a shell is to be seen; for example, in the greater part of Ross Island and in some of the adjacent islands.

(25.) It is not improbable that a connexion subsists between the Killarney transition limestone and that which appears in the Drishane quarries near Millstreet, traces of limestone having been observed in the boggy tract which intervenes. The Millstreet band ranges south of the Blackwater river, past Clonemeen to the east of Roskeen bridge, terminating at a short distance from the latter in the greywacke and slate country. In most places it is amorphous, but where the strata are distinctly developed, they dip to the south, at angles varying from 45° to 70°, yet subject to curvatures, corresponding with those in the adjacent greywacke and slaty rocks. This limestone is generally of a light colour, and it exhibits few distinct organic reliquiæ, the chief or most characteristic being a species of Avicula, assembled casually in interlaced groups, forming a thin separate layer.

(26.) The band of light-coloured limestone which ranges from the east of Aglish past Tallow to Castle Lyons on the west, may be seen adjacent to the first-named village, reposing on and alternating with clay-slate, both formations, where in contact, dipping to the southward at an angle of 45°, and containing the *Producta depressa*, some Spiriferæ, Polyparia, and crinoidal re-

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mains. The broken portions of Crinoidea are very frequent in the limestone. The general range of the conjoining slaty and other rocks on the northern side dip to the south, and on the southern side to the north, commonly at high angles, to which the limestone appears to conform, its more central strata approaching the vertical position, as may be observed in the Tallow district.

On the northern side of this limestone band, in the range of hills which extends eastward to the southern part of Dungarvan harbour, may be observed numerous varieties of greywacke, sandstone, quartz-rock, and slate, frequently of a reddish brown hue, also of a yellowish or whitish cast, the sandstone and greywacke affording, in some places, tolerable freestone for building purposes. Many coarse conglomerates occur also in the series, containing fragments and pebbles of considerable size.

(27.) Proceeding S. from Aglish to Clashmore, a distance of about five miles, the slaty rocks undergo interchanges of the dip from N. to S., and again to the N., vertical strata intervening. Between Clashmore and Ballyhenny we cross a band of limestone about half a mile wide, which ranges nearly two miles E. and W., included in clay-slate, these rocks all dipping in conformity 75° to the N. The slate is partly interlaminated with the limestone, where it underlies the latter. Lydian-stone occurs occasionally in the limestone, in layers a few inches thick, and also in interspersed portions. The latter rock is mostly dark bluish grey, containing chiefly small fragments of crinoidal remains and of some few bivalves. At a little distance S.E. of Ballyhenny limestone quarry, roofing-slate is raised.

(28.) To the N. of the town of Youghall is a band of light-coloured limestone, which, proceeding from the vicinity of Clasheen on the W. past Kilnatoara Castle and river, seems to cross the harbour, reappearing on the E. in Pilltown, and extending thence to the small bay of the sea situated to the N. of Ardmore Head. It may average half a mile in width, and both at Pilltown and Kilnatoara Castle quarries the strata dip 80° to 85° to the N., or approach the vertical. The slaty rocks immediately north of this limestone dip south, and on the south to the north, but in both cases at high angles; while still further north and south the dips are interchangeable, so that the general series may be considered as nearly vertical. In the Pilltown limestone are few well-marked organic remains, and they are chiefly crinoidal, as also in that of Kilnatoara. In the latter I did not observe a single bivalve, but I obtained a broken portion of what appears to be a Goniatite of Von Buch.

(29.) South of Youghall we enter upon the principal band of limestone contained in the transition tract, extending from Youghall Bay on the east,

past Carrigtohill and Cork to Castlemore on the west. In this range the limestone, after reaching the upper part of Cork harbour, occupies the smaller islands in that quarter, together with the northern points of Cove Island, thence pursues its western course on the south side of the Lee to the confluence of that river with the Bride, then lines both banks of the latter stream for a short distance, while the remainder of its course is confined to the right bank, terminating at about a quarter of a mile to the west of Castlemore Castle, or nearly fifteen miles west from Cork. This band in its broadest part, on the east, is between four and five miles wide, while at Castlemore, on the west, it is reduced to about half a mile in breadth. Flanked throughout by hilly ranges of slaty and greywacke rocks, the general dip is to the south, varying chiefly between angles of 70° and 80°, yet often approaching the vertical, and in some parts exhibiting a counterdip to the north. These relations may be distinctly observed, in traversing the bounding slaty rocks and the limestone from north to south, in different portions of the range, both to the east and the west of Cork harbour. The limestone is generally light-coloured and continuous, free from foreign beds, and the few organic remains I have seen in it were chiefly crinoidal.

(30.) A similar arrangement is observable in the parallel band of limestone, which, proceeding from the sea on the east, passes through the vale of Cloyne to Cork harbour, where it occupies the northern part of Spike Island, the south-western point of Cove Island, the whole of Rocky Island, and the isles of Haulbowline and Rinniskiddy; thence passing to the main land, it composes the projecting points of the coast as well as the strand of Rinniskiddy village, and proceeding west, it passes by Shanavally and Hawksglen to Shannon Park*. The interlamination of this band of limestone on its southern side, with the adjacent clayslate of Rinniskiddy hill, is distinctly seen in the rocks upon the strand, all approaching the vertical position, yet dipping south. The great body of Rinniskiddy hill is composed of clayslate, corresponding with the southern part of Spike Island; but in passing round the former along the strand, we find toward its southern side, the slate containing, at considerable intervals, discontinuous layers of limestone, each a quarter or half an inch wide. Further south these beds become more frequent and thicker, until they exceed those of the clayslate in dimensions and number, and in the more southern portion of the hill are nearly continuous. We have thus entered upon another parallel band of limestone, which ascends about halfway up the southern face of Rinniskiddy hill, and occupies the flat of the inlet below, ranging to the westward by Coolmore to Carrigoline; and to the eastward it

* The scale of the Map does not permit the whole of these places to be laid down.

apparently passes under the sea to Corkabeg, terminating there in a low promontory, which extends from the mainland on the eastern side of the lower harbour, being situated to the north of Carlisle Fort. The clayslate, interlaminated with the limestone both on the northern and southern sides of Rinniskiddy hill, contains the same organic remains as the latter rock, and the series of strata deserves strict examination from those, whose local residence may afford the requisite leisure and opportunity. The fossils I met with were mostly indistinct. All these rocks dip conformably to the south.

(31.) In the ranges of clayslate hills which occupy the district on the south of the limestone of the vale of Cloyne, is an isolated but parallel band of limestone, situated about half a mile south of that of the Cloyne valley. It ranges in a dell from east to west nearly two miles, being about one eighth of a mile in thickness; and, as exposed in the principal quarries of Carrigacrump and Ballyfin, its strata appear on the northern side, dipping 70° to the south, corresponding in that respect with the adjacent clayslate on the north; but in proceeding south the limestone approaches to the vertical position.

(32.) I have yet to notice two small isolated bands of limestone in the greywacke and slate series, the one situated at Blarney, north of the river Lee, the other adjacent to that river and south of Macroom.

At Blarney the limestone forms a ridge of slight elevation, about two miles in length, ranging east and west, in strata apparently nearly vertical. Blarney Castle is situated about midway between the two extremities of the ridge, which becomes narrow toward the east, but widens toward the west; its greatest width being nearly half a mile. The red slate and greywacke rocks which bound this limestone on the north and south, approach the vertical position, yet with a prevailing dip toward the south, though the northerly dip also occurs. High, hilly ground, about two miles wide, intervenes between the Blarney limestone and the river Lee.

The band of limestone south of Macroom, stretches along the right bank of the river Lee to an extent of two miles, but in its progress west it crosses that river, proceeding about half a mile further. It nowhere appears to exceed half a mile in width, and its general position may be considered as vertical, the slaty and greywacke rocks by which it is bounded, being on the south either vertical, or inclined north, and on the north inclined south, yet nearly vertical; while still more north and south the dip becomes interchangeable, high angles in these cases always prevailing. In the hills flanking this limestone, and also in the defiles which lead toward the Castlemore limestone in the valley of the Bride (§. 29), may be observed many varieties of greywacke, quartz-rock, and slate, of varying shades of blue, green, brown, red, and grey.

In the limestones mentioned in §§. 31 and 32 organic reliquiæ appear very sparingly.

(33.) In addition to the organic remains noticed by me in the transition limestone in the preceding §§. 21 to 32, I here subjoin a list of those observed by Mr. S. Wright in the Cork limestones, for which list and their localities I am indebted to that gentleman, almost all the species having been determined by Mr. James de Carle Sowerby. The locality given as Cork, implies that the species were derived from quarries near that city, in the direction of the village of Evergreen; while that of Ballinlough denotes a position nearly half way between the city and the extremity of the peninsula of Black Rock. To the localities of those species which have been found also in the transition tracts of Great Britain or other countries I have affixed the mark †; to those occurring also in the carboniferous limestone of Ireland, the mark *; and to such as have been met with likewise in the carboniferous limestone of Great Britain or other countries, the mark ‡. From this list it will be obvious that many species of Productæ, Spiriferæ, and Terebratulæ, in particular, are common to both the transition and carboniferous epochs. For many of the distinct localities of these and other organic remains specified, reference may be further had to Sowerby's Mineral Conchology; the 3rd edition of Mr. De la Beche's Geological Manual, 1833; the German modified translation of the 2nd edition of the same work by M. von Dechen, 1832, and the French translation of the 2nd edition of same work by M. Brochant de Villiers, 1833 (the latter being distinguished by very useful references to the published *figures* of fossils, as well as by other additional matter); also the excellent work on Geology in the Encyclopedia Metropolitana by Professor Phillips; and to other authors[1].

Crustacea.		*Localities in South of Ireland.*	*In other Transition Tracts.*
Two species of Trilobite, undetermined		Black Rock.	
The tuberculated species of Asaphus, figured by Brongniart, Plate IV. fig. 12. (*Asaphus gemmuliferus* of Professor Phillips)	*‡	Cork.	
Cephalopoda polythalamia.			
Orthoceras striatum, (Sow. T. 58.)	*	Black Rock.	† { Malmoe; Christiania; Trenton Falls, (New York.)
O. Breynii, (Sow. T. 60, fig. 5.)	*‡	Ditto.	

[1] This list may serve to clear up some doubts expressed by Professor Phillips in the Encyclopedia Metropolitana, art. Geology, pp. 577 and 578, as to the occurrence of certain fossils in the transition limestone of the South of Ireland. Compare also with pp. 572 to 576, and pp. 579 to 581 of the same work, which have reference to the fossils of transition tracts in general. With the view of drawing the attention of geologists further to this subject and exciting inquiry, I have appended a note to each of the lists of the Productæ, Spiriferæ, and Terebratulæ, found in the Cork limestones, showing what other species of these genera are stated to have been discovered both in the transition and carboniferous systems of other countries.

		Localities in South of Ireland.	*In other Transition Tracts.*
Orthoceras fusiforme, (Sow. T. 588, fig. 1, 2.)	*‡	Black Rock.	
Nautilus globatus, (Sow. T. 481.)	*‡	Ditto.	† Trenton Falls.
N. multicarinatus, (Sow. T. 482. figs. 1, 2.)	*‡	Ditto.	
N. cariniferus, (Sow. T. 482, fig. 3, 4.)	‡	Ditto.	
N. sulcatus, (Sow. T. 571, fig. 1, 2.)	*‡	Middleton.	
N. Wrightii (Fleming), considered as identical with *N. globatus*		Black Rock.	
N. ovatus, (Ellipsolites of Sow. T. 37.)	*	Ditto.	† Hof; Schleitz.
N. funatus, (Ditto, Sow. T. 32.)		Ditto.	
N. compressus, (Ditto, Sow. T. 38.)		Ditto.	
Gasteropoda.			
Euomphalus triangularis, (Wright.)		Cork.	
E. ovalis, (Wright.)		Ditto.	
E. pentangulatus, (Sow. T. 45, fig. 1, 2.)	*‡	Ditto.	† Dudley.
E. catillus, (Sow. T. 45, fig. 3, 4.)	*‡	Black Rock.	† Dudley; Blankenheim.
Pileopsis vetusta, (Sow. T. 607, fig. 1, to 3.)	*‡	Little Island; Cork.	† Plymouth; near Ludlow.
Ampullaria helicoides, (Sow. T. 522, fig. 2.)	*‡	Cork.	
A. ovalis, (Wright.)		Black Rock.	
Solarium, (Wright.)		Ditto and Cork.	
Nerita spirata, (Sow. T. 463, fig. 1, 2.)	‡	Black Rock.	† Plymouth.
Conchifera.			
Producta Scotica, (Sow. T. 69, fig. 3.)	*‡	Black Rock.	† Isle of Man; Eifel.
P. Martini, (Sow. T. 317, fig. 2, 3, 4.)	*‡	Ditto.	
P. concinna, (Sow. T. 318, fig. 1.)	*‡	Cork.	
P. lobata, (Sow. T. 318, fig. 2 to 6.)	*‡	Black Rock.	
P. punctata, (Sow. T. 323.)	*‡	Ballinlough.	
P. antiquata, (Sow. T. 317, fig. 1, 5, 6.)	*‡	Black Rock.	
P. plicatilis, (Sow. T. 459, fig. 2.	‡	Ditto.[1]	

[1] Of the above species of Productæ, the *Producta Scotica* alone appears to have been hitherto noticed in the transition series of other countries; but the following species of Productæ are enumerated as having been found both in the transition and carboniferous systems:

	Transition.	*Carboniferous.*
Producta depressa, (Sow. T. 459, fig. 3.)	† South of Ireland; Dudley; Eifel.	* Fermanagh‡; Liege.
P. hemisphærica, (Sow. T. 328.)	† Eifel; Albany; (New York.)	‡ Ratingen; Liege. * Buttevant, (Wright.)
P. longispina, (Sow. T. 68. fig. 1.)	† Blankenheim	‡ Linlithgow.
P. sulcata, (Sow. T. 319, fig. 2.)	† Catskill Mountains	‡ Derbyshire; Visé; Liege.
P. anomala, (Sow. MS.)	† Plymouth	‡ Preston.
P. sarcinulata, (Goldfuss)	‡ Eifel	‡ Visé.

(See the French translation of Mr. De la Beche's Geol. Manual. The *Producta depressa* in Fermanagh was discovered by Prof. Phillips.)

P. scabricula, (Sow. T. 69.)	†	Eifel	‡ Derbyshire; Liege; Visé (Von Dechen).

(*Conchifera.*—continued.)	*Localities in South of Ireland.*	*In other Transition Tracts.*
Spirifera cuspidata, (Sow. T. 120.).....	* Black Rock.	† Plymouth; Eifel; Coblentz; Blankenheim.
S. distans, (Sow. T. 494, fig. 3.).....	* Ditto.	† Plymouth.
S. oblata, (Sow. T. 268.).....	*‡ Ditto.	† Norway.
S. trigonalis, (Sow. T. 265.).....	*‡ Ditto.	
S. radiata, (Sow. T. 493, fig. 1, 2.)	‡ Cork.	† Dudley.
S. striata, (Sow. T. 270.)	*‡ Ballinlough.	† Dudley.
S. pinguis, (Sow. T. 271), considered by Von Dechen as identical with *S. lævicosta* of Goldfuss	*‡ Ditto.	† Eifel; Coblentz; Bensberg.
S. octoplicata, (Sow. T. 562, fig. 2 to 4.) .	*‡ Little Island, Cork.	† Plymouth; Eifel; Gottland.
S. resupinata, (Terebratula, Sow. T. 325.)	*‡ Ballinlough.	
S. rotundata, (Sow. T. 461, fig. 1.)	*‡ Cork.[1]	† Newton Bushel.
Terebratula crumena, (Sow. T. 83, fig. 2, 3.)	*‡ Black Rock.	† Eifel; Lindlar.
T. hastata, (Sow. T. 446, fig. 2, 3.)	*‡ Ditto.	
T. sacculus, (Sow. T. 446, fig. 1.)	*‡ Ditto and Middleton.	† Blankenheim.
T. lateralis, (Sow. T. 83, fig. 1.)	*‡ Black Rock.	† Eifel; Blankenheim.
T. cordiformis, (Sow. T. 495, fig. 2, 4.)..	* Ditto.	
T. lævigata, (Schlot. T. 18, fig. 1.) Spirifera, considered by Von Dechen as identical with *S. oblata* of Sowerby	*‡ Ballinlough.	† Norway.
T. pugnus, (Sow. T. 497.)	*‡ Black Rock.	† Plymouth; Newton Bushel; Eifel.
T. reniformis, (Sow. T. 496, fig. 1 to 4.)	*‡ Ditto.[2]	
T. acuminata, (Sow. T. 324, fig. 1.)	‡ Ballinlough[3].	† Eifel.
Isocardia oblonga, (Sow. T. 491, fig. 2.) ..	Black Rock and Little Island in the South of Ireland.	

[1] Of other Spiriferæ occurring both in the transition and carboniferous series, Prof. Phillips enumerates the following species, (see Encyclopedia Metropolitana, art. Geology, pp. 576 and 605.)

	Transition.	*Carboniferous.*
Spirifera glabra & obtusa, (Sow. T. 269.)	† Plymouth	‡ Derbyshire; Ratingen; Liege.
S. attenuata, (Sow. T. 493, fig. 3, 4, 5.)	† Eifel; Coblentz ..	* Dublin; ‡ Liege.
S. ambigua, (Sow. T. 376.).....	† Blankenheim	‡ Derbyshire. Ratingen.
S. reticulata, (Sow. MS.).....	† Plymouth	* Ireland.
S. decurrens, (Sow.).....	† Newton Bushel ..	‡ Daddy's Hole, near Torquay. (De la Beche.)
S. striatula, (Goldfuss).....	† Eifel; Bensberg; Christiania; Trenton Falls.	‡ Ratingen, (Von Dechen.)

[2] Both Von Buch and Sowerby consider *T. reniformis* and *T. lateralis* as varieties of *T. pugnus*. See "*Ueber die Terebrateln, mit einem Versuche, sie zu classificiren und zu beschreiben*, von Leopold von Buch. Berlin, 1834." p. 34.

[3] Of other Terebratulæ met with both in the transition and carboniferous systems, Professor

(*Conchifera*—continued)	*Localities in South of Ireland.*	*In other Transition Series.*
Cardium hibernicum, (Sow. T. 82, fig. 1,3.) *Pleurorhynchus hibernicus* of Phillips....	* ‡ Cork and Black Rock[1].	
Polyparia.		
Cyathophyllum	Cork.	
Favosites.....	Little Island.	
Retepora	Black Rock and Cork.	
Amplexus coralloides, (Sow. T. 72.)	* ‡ Cork.	† Eifel; Mont Chatou near Coutances; Catskill Mountains, (New York.)
Crinoidea.		
The Actinocrinites 30-dactylus.....	* ‡	† Eifel.
And many other crinoidal remains occur in fragments in the	Cork limestones generally.	

To this list I have to add that casts, apparently derived from the concavity of vertebræ of fish, have also occurred in the Cork limestone; and which were, I believe, first recognised as such by the late Mr. J. S. Miller.

Metalliferous Relations of the Transition Tract[2].

(*a.*) *In the greywacke and slate districts.*

(34.) The metalliferous indications appearing on a part of the Waterford south coast, lying immediately east and west of the Bonmahon river (§. 18.) have

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Phillips gives the following list. (See Encyclopedia Metropolitana, art. Geology, pp. 577 and 605.)

	Transition.	*Carboniferous.*
Terebratula Mantiæ, (Sow. T. 277, fig. 1.)	† Ems; Blankenheim ..	* Ireland.
T. platyloba, (Sow. T. 496, fig. 5, 6.)..	† Plymouth	‡ Clithero.
T. plicatella, (Dalman).....	† Plymouth; Gottland ..	‡ Ratingen, (Von Dechen.)
T. diodonta, (Dalman)	† Eifel; Gottland.....	‡ Ratingen, (Von Dechen.)
And according to Von Dechen, T. affinis, (Sow. T. 324, fig. 3,) T. prisca, (Schlot. T. 17, fig. 2.).....	† South of Ireland; Dudley; Plymouth; Eifel; Bensberg; Gottland..	‡ Derbyshire; Liege; also* Buttevant, (Wright.)

[1] This is not now considered a Cardium. Professor Phillips brings it under a new genus, named by him, as above, Pleurorhynchus. The common form in which this shell appears is as figured by Sowerby; but in three instances I have found attached to the broader end of the shell a flattened rim round its border, while from the projecting part of the broad end proceeds a long tubular spinous process. Viscount Cole informs me he has seen this process in a large individual, extending to the length of three or four inches.

[2] I have long been persuaded of the importance of placing upon record an account of the geological circumstances of mines, for independently of the light they assist in throwing on the physical structure of the earth, they afford practical information to the miner and the landed proprietor, and may often prevent a wasteful application of capital.

This latter evil might be remedied to a certain extent, if a legislative enactment were made,

given rise to mining operations at different periods, which seem in general to have been attended with little advantage. The greater part of the workings were shallow.

To the westward of the river such operations were conducted upon fifteen different veins in the face of the cliffs, three being worked for lead, and the remainder for copper. Latterly, researches have been extended more inland, upon some old workings at Monachoe, to a depth exceeding fifty fathoms, but they yielded only a small quantity of copper ore, the vein not having improved in depth. On the other hand, on the east of the river, a vein of copper ore discovered more recently at Ballinasisla, yielded valuable returns to a considerable depth, but latterly it has become nearly barren. On this part of the coast the old trials were conducted on seven veins for copper, and two veins for lead.

These metalliferous veins affect, for the most part, a nearly north and south course, the dip being to the east or west, or to both in the same vein at different depths. They, however, frequently ramify both on the line of range and dip.

(35.) The metalliferous relations in the county of Cork, refer chiefly to the lead mines of Ringabella and Doneen, and to the copper mines of Audley, Ballydehob, and Allihies.

(36.) In the small inlet of Ringabella, on the western side of the entrance to Cork harbour, the slate, which is displayed on both banks, ranges east and west, and dips 80° south, and on the south side of the inlet rises a small low hill, in which is situated the Ringabella lead mine. This undertaking is conducted on a bed in the slate, composed of quartz and sparry iron ore with interlaminated slate, which contains galena, pyrites of copper and iron, and some calcareous spar. It is irregular in form, varying from a few inches to one and a half feet in width. The two first-mentioned substances predominate, the sparry iron ore often forming a drusy assemblage of crystals. The lead ore appears in bunches, the copper ore is sparingly disseminated, while the iron pyrites is more abundant. I am informed that the trial has not been conducted to a greater depth than twenty fathoms*.

(37.) In the southern cliffs of Doneen Inlet, on the western side of Clonekilty Bay, are the remains of old works, close to the sea, conducted, as reported, to the depth of thirty or forty fathoms. Judging by those remains, the object of research would appear to have been a bed in the slate, between one and two feet wide, composed of sparry iron ore and quartz, with disseminated galena, and pyrites of copper and iron, and hence, in formation, bearing considerable analogy to that noticed in the Ringabella mine.

The range of the slate on this part of the coast is generally east and west, the strata being nearly vertical, or inclined at a high angle to the south.

Upon the strand below the northern cliffs of Doneen, are displayed beds of sulphate of barytes, with intervening strata of slate, the former being mostly compact, or minutely granular-foliated, with some appearances also of the large lamellar structure. There are three of these beds, the

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obliging all adventurers in mines to lodge among the records of the county, in which any such mine was situated, a plan and section of the mine when abandoned, together with a report of its then state and circumstances, and the cause of its abandonment.

* It is in the slate of Spring Hill, situated on the northern side and near the western extremity of Ringabella inlet, that the fine specimens of the Cork wavellite have been obtained.

northern being one and a half to two feet wide, the middle one about four feet, and the southern six or eight inches; the interval of slate between the first and second beds being three to five feet, and between the second and third, twenty feet. These beds contain only a few specks of pyrites of iron and copper, and some galena sparingly disseminated. In their arrangement they are nearly rectilinear; but about ten fathoms north of the northern bed of sulphate of barytes, the slate forms acute-angled inflections, which are exhibited in a horizontal section.

(38.) In the Audley mines, which are situated about ten miles south-west of Skibbereen, the metalliferous deposits are also contemporaneous with the rock, which consists of slate more or less quartzose, and passing into quartz-rock. The principal workings are on the town-land of Cappagh, conducted on a metalliferous bed, the inclination of the strata being at an angle of 80° to the south. The bed generally consists of quartz, accompanied by purple and green copper ores, but sometimes the quartz disappears, and the metalliferous deposit is confined to the slate alone, appearing in strings and flakes. The bed has varied in its course from an inch and less to two feet and a half in width, forming separate bunches connected by a leader; and it is occasionally joined and traversed by contemporaneous veins of quartz, most of which are barren, but some contain also interspersed specks of purple and green copper ores. North of this bed is a second of a similar nature, which being only at a short distance, is wrought at the same time. These workings have been extended upwards of seventy fathoms in depth*.

South of Cappagh mine the slate, after having become vertical, gradually acquires the northerly dip, which prevails also throughout Horse Island, adjacent on the south, varying here from 45° to 60° above the horizon. Here also may be occasionally observed a thin layer of slate (commonly varying from a line to three or four inches in width), which is penetrated with cupreous particles, namely, slight flakes of green carbonate of copper scattered between the laminæ and in the fissures of the rock, accompanied by disseminated purple copper ore; and a similar layer sometimes contains also quartz and a small portion of calcareous spar. Quartz veins likewise frequently traverse the rock, mostly ranging in the direction of the dip of the slate, and varying from a line to two, three, or four inches wide; but they often terminate at the distance of two or three feet. They are mostly barren, yet some contain slight flakes of the green carbonate, and specks of the purple sulphuret of copper; chlorite also is not uncommon. In the vicinity of these veins the slate is very quartziferous, and in some of the layers may be incidentally observed, interspersed particles of pyrites of copper and iron.

A similar diffusion of metallic particles occurs in the slate of the townlands of Filemuck and Ballycomisk, which flank Cappagh on the north; seven discontinuous layers being disposed there, somewhat in an echelon order, and having given rise to as many different trials. The greater part of these trials extended only about ten feet, while one of them was 24 feet in depth; but the principal, called Ballycomisk mine, was carried down to the depth of 20 fathoms, yet the working in the bottom seldom exceeded six fathoms in length, being that of the main bearing of ore. This was conducted on a bed of quartz mixed with slate, about two feet wide, containing yellow copper ore, specular and micaceous iron ore, some sulphate of barytes, iron pyrites, and a little purple copper ore. The cupreous deposits in some of these trials, have extended occasionally to the width of three or four feet in the rock.

(39.) Analogous relations to those now described (§.38), occurred at the Ballydehob mine on

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* The Cappagh purple copper ore is sometimes accompanied with bismuth. An intermixture of these substances, analysed by Mr. Edmund Davy, Professor of Chemistry, Royal Dublin Society, yielded 45 per cent. of copper, and 20 per cent. of bismuth.

Mr. Swanton's estate, situated about one and a half mile north of Cappagh. The works here extended about 20 fathoms in depth.

Some similar indications of ore occur on Lord Audley's property adjoining the Ballydehob mine; also on Mr. Becher's estate, lying about one mile and a half to the north-west; also, one mile and a half further in the same direction, on Mr. Teulon's land in Gurtinakilly. A similar occurrence is to be observed about two miles south of Skibbereen on the townland of Moneyvolan, Colonel Townsend's property; and again in Hare Island, south-east of Horse Island.

This diffusion of cupreous particles through a portion of the county of Cork is remarkable; and it is to be hoped that the indications may lead to the discovery of some valuable deposit.

(40.) *Cupriferous peat-bog.* In the year 1812 there existed on the eastern side of Glandore harbour, a peat-bog occupying a small dell, and extending over a very few acres, which was found charged with copper. The peat was in consequence cut out, burnt, and the copper thus became concentrated in the ashes. Forty or fifty tons of the dry peat produced about one ton of cupriferous ashes, which were sufficiently rich to yield a remunerating price when sold. Some of the ashes are said to have contained as much as 10 or 15 per cent. of copper. This discovery led to some trials in the vicinity with a view to find the source of the saline impregnation. In these researches, however, there were met with in the soil, only detached portions of iron ore and manganese, partly blended with quartz and sulphate of barytes. It seems not improbable that this deposition of copper in the bog, originated in the decomposition of some of the sulphurets of copper, contained in the vicinage, either in a metalliferous bed, or partially disseminated in the rock; both of which cases, we have shown, are not of uncommon occurrence in this part of the island.

Quarries of roofing-slate are worked near Glandore harbour, and other parts adjacent to the south coast; and of this slate considerable use is made in the country. But it cannot vie either with the Welsh or the Valentia slate.

(41.) One of the most valuable copper mines in Ireland is that of Allihies, situated in the south-western extremity of the county of Cork, facing the entrance of Kenmare bay. It was discovered by a Wicklow miner in the year 1812, and it has been since wrought with great success, having yielded upon an average more than two thousand tons of merchantable ore per annum, which has been sold in the Swansea market, in general, at the rate of about £10 per ton. This body of ore has been derived from a powerful vein of quartz, which is of variable dimensions, but has in some parts been found enlarged to the breadth of thirty feet. The principal deposits of ore have occurred adjacent to the walls. The vein ranges in general in a north and south direction, intersecting the slaty rocks of the country, but in a part of its course it also runs parallel with the slate. The chief workings have been extended to a depth exceeding fifty fathoms, the prevailing ore being copper pyrites.

(*b.*) *In the Transition Limestone.*

(42.) The transition limestone of the South of Ireland has hitherto been found productive of metal in the county of Kerry alone; viz., in the lead mines of Kenmare, and in the copper mines of Muckruss, Ross Island, and Crow Island.

(43.) The Kenmare limestone field (§ 23.) extends from west to east, through the following properties, opposite to which are placed the indications of metals observed in each respectively.

TOWNLAND*.	PROPRIETOR.	INDICATIONS.
Reens.....	Mr. Langford.	Galena, copper pyrites, and blue and green carbonates of copper, with calcareous spar.
Dunkerrin.....	Dr. Thos. Taylor.	Galena.
Tibburid.....	Rev. Mr. Mahony.	Iron ochre, galena, and iron pyrites, with calcareous spar.
Gurtamullin	Ditto.	
Kenmare town.....	Marq. of Lansdowne.	Galena with calcareous spar.
Killowen.....	Ditto.	Galena, blende, iron pyrites, and iron ochre, with quartz and calcareous spar.
Gurtagass & Cleady,	Trinity College, Dublin.	None observed.
West Cahir	Marq. of Lansdowne.	Iron ochre, blende, galena, iron pyrites, and green carbonate of copper, with calc. spar.
East Cahir.....	Ditto.	None observed.
Clontua.....	Mr. J. Dillon Croker.	Galena, blende, iron pyrites, yellow, grey, and purple sulphurets of copper, with blue and green carbonates, and calcareous spar.
Ardtully Proper....	Ditto.	Iron ochre, and copper pyrites, with calc. spar.
Kilpadder.....	Mr. Townsend Orpen.	Copper pyrites, with calcareous spar.

In the slate, adjoining the limestone on the north, are also the following indications.

In East Cahir.....	Compact indurated oxide of iron.
In Clontua.....	Green carbonate, grey and purple sulphurets of copper, and indurated oxide of iron.

The above-mentioned metalliferous indications appeared for the most part of a confined, local character, bespeaking no permanent extension: yet, some seeming to deserve research by actual working, trials were made in Killowen in separate places to the respective depths of 42, 33, and 15 feet; in West Cahir to the depths of 45, 46, and 25 feet; and in Ardtully Proper to the depth of 15 feet. But in all these cases, however promising the appearances at the surface, the mineral deposits proved discontinuous, dividing and contracting so as finally to disappear, and thus penetrating the rock only to a small extent either in length or depth; yet in their position they were always nearly parallel to the range and dip of the bed in which they were included.

The same results clearly followed the researches of former adventurers, made on the lands of Reens and Kilpadder, extending only a few fathoms in depth. The most extensive of the old trials were made in Clontua in the form of four open-casts, respectively 60, 80, 28, and 10 fathoms in length, two being on the same range, and two parallel to each other. The deepest did not exceed 6 or 7 fathoms in depth, while none of the others penetrated beyond 10 feet. In these trials, as in others already mentioned, were chiefly found layers of calcareous spar of uncertain continuity, and bearing ore more or less sparingly.

Researches were also made in the slate, north of the limestone, in East Cahir and in Clontua. In the former, the old adventurers had made an extensive open-cast and sunk some pits; but no ore appeared at the surface beside indurated oxide of iron. Workings, more recently instituted,

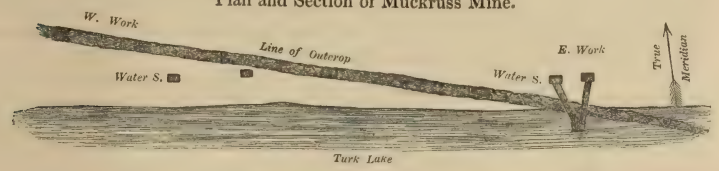
* The scale of the map does not permit the position of the townlands to be laid down.

traversed merely diluvial matter, among which was found only the same indurated oxide of iron. This mineral therefore was probably the object sought with a view to the manufacture of iron, at a time when the superabundant forests of the country were made applicable to that purpose*.

In Clontua, adjacent to the limestone, five shafts had been sunk in the slate upon an E. and W. line, apparently 9 or 10 fathoms deep. New workings, conducted to the depth of 13 fathoms, discovered in the slate only a few strings of quartz with lenticular nodules of calcareous spar, containing grey and yellow copper ores in filaments or minutely disseminated, which on being pursued disappeared altogether.

(44.) The Muckruss mine consists of two works, an eastern and a western, conducted apparently (as indicated in the annexed plan and section), in the same bed of slate, included in the limestone adjacent to Turk Lake (§. 24.), and from one to three feet wide.

Plan and Section of Muckruss Mine.



Scale,—Twenty fathoms to one inch.

Both the eastern and western works were undertaken about the middle of the last century. In the latter rich yellow and grey sulphurets of copper prevailed, while in the former the ores consisted chiefly of copper pyrites accompanied by much iron pyrites. In the western work was found also a layer of arsenical cobalt ore from half an inch to two inches wide, and more or less intermingled with the copper ores. The cupriferous bed of slate is represented as interwoven with layers and laminæ of limestone, and layers and veins of calcareous spar, in which the copper ores were contained in layers, strings, and disseminated; but the ends of the workings having become narrower and less productive, the mine was abandoned†.

The eastern work was resumed in 1785, and again in 1801, but not continued. The bottoms were then stated to be 22 fathoms deep. The western was resumed in the year 1795, and again reopened in 1818, when on the examination of an able Cornish miner it was reported to be poor and unpromising. The bottoms are said to be 28 to 30 fathoms deep from the surface.

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* The former excavations may have been made by the English colony planted at Killowen in the year 1670 by Sir William Petty, as it is stated that these people were employed in *iron works* and a fishery.—See Smith's History of Kerry, p. 317.

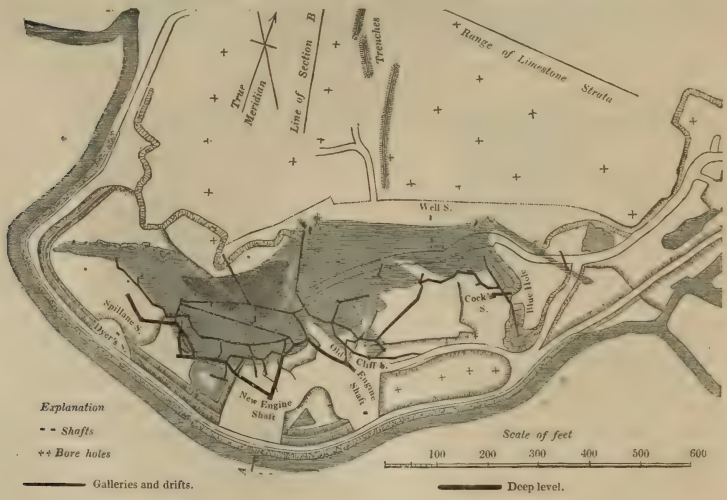
† According to Smith's History of Kerry, p. 125, the Muckruss mines yielded in one year, after the works commenced, 375 tons of copper ore, which produced 26⅔ per cent. of copper.

The outcrop of this bed at the surface appears in the form of iron ochre, which in the western part contains some intermingled portions of galena.

(45.) The earliest working of the Ross Island mine, is ascribed to the times of the Danish inroads; and the shallow parts above the level of the lake were evidently wrought by fire, being composed of chambers of a rudely vaulted form. The works have been resumed at various periods; one of the latest was in the year 1804, from which time the operations were continued until 1810. In this interval 3220 tons of ore were raised, the sale of which amounted to 69,487*l.*, being on an average about 21*l.* per ton; and the standard price of copper during those years having averaged 135*l.* per ton, the ores appear to have yielded $17\frac{1}{2}$ per cent. of copper.

In the year 1825 my attention was drawn to this mine, then filled with water, the level of which corresponded with that of the lake. The mine had been represented by some as a metalliferous bed, dipping to the south at an angle of 16° from the horizon, yet partially connected with irregular contemporaneous veins; while by others it was considered as a rake vein. In reference to what follows, the annexed plan and section of Ross Island mine will be found serviceable. They represent the state in which the mine was left in the summer of 1829.

Plan of Ross Island Mine with the Embankment.



Section of Ross Island Mine and Embankment from S. to N. on the line A—B.

To redeem this mine I devised the following plan: 1. To form an efficient embankment, drawn from the west to the east through the deep water on the south, thus gaining a considerable portion of land from the lake: 2. To sink a new engine-shaft south of the old mine, intercepting in greater depth the metalliferous bearing, and forming there new workings: 3. To drain, in the mean while, the old mine by horizontal rods extending from the new engine-house to the old engine-shaft: 4. and lastly, By connecting the new with the old workings, to render the new engine-shaft the central point of drainage.

The preliminary works having been completed in sixteen months, the drainage was effected in May 1827. The succeeding operations showed that the real geological circumstances of this mine had never been clearly understood. They proved, in fact, that the mine was not wrought upon a metalliferous bed, nor upon any real rake vein or true lode; but that the metallic deposits formed a portion of, and were contemporaneous with the rock mass itself; being most unequally and irregularly distributed in the form of isolated portions, branches, strings, and particles of ore minutely disseminated, in a manner quite analogous to the strings, filaments, and other portions of calcareous spar which are also embodied in the substance of the limestone mass. Though thus irregularly incorporated with the rock, the general disposition of the metalliferous ground assumed an east and west range with a southerly dip, but without any wall or decided line of partition, so that the form of the excavation, made in any case, depended wholly on the extent to which the ore was disseminated, laterally as well as longitudinally, and deserved extraction.

In the plan the shaded space indicates the extent of the excavations upon ground productive of ore, its northern extremity showing the actual outcrop at the surface upon an inflected line from east to west, and its southern extremity denoting the irregular limits of the metallic deposits in their inclination to the southward. The dip of the excavations thus formed, is exhibited in the section. The northern (*ore-ground*) inclines in general at an angle of 16° from the horizon, and the southern (*ore-ground*) at an angle of 35°; but to the westward they collapse, run together, and are finally attenuated in the form of a thin wedge. On the other hand, to the eastward, the southern body of ore-ground extends only a short distance beyond the meridian of the New Engine Shaft, while the northern body becomes in the eastern direction gradually more and more contracted in its dimensions, terminating, beyond the excavation called the *Blue Hole*, in occasional slight filaments and particles of ore, dispersed through the rock, unworthy of pursuit. The workings in the Blue Hole itself were conducted in the northern part on discontinuous branches and strings of yellow copper ore; and in the southern part chiefly on irregular masses imbedded in the rock, which consisted of an unprofitable compound of blende, galena, and iron pyrites, with a slight intermixture of copper ore. Yet considerably to the westward, adjacent to the Cliff shaft, an isolated, profitable bearing of good yellow ore was met with, but this did not ascend to the surface.

In short, Ross Island consists for the greater part of what may briefly be called the *siliceous limestone*, namely, a series of thin, alternating beds of limestone, hornstone, quartz, and lydian stone, with some few of clay-slate interposed. This series supports, at the southern angle of the isle, continuous, thick strata of blue limestone, which form a body, in its highest part, from ten to twelve fathoms in thickness, and, in its lowest part, about six fathoms. The blue limestone rests in a perfectly conformable position upon the siliceous limestone, the inflection of the two kinds of rock corresponding throughout, rising

and outcropping to the north at an angle of 40° to 45°, but in descending to the south, gradually flattening to an angle of 6° or 7°, and on approaching the lake becoming absolutely horizontal. The line of division thus marked in the section, between the two descriptions of limestone, serves to indicate correctly their coinciding stratification; and by the miner it is familiarly termed the *flat bed*. The juxtaposition of the two rocks is, in most cases, so close as scarcely to admit the blade of a knife; but in some places the line of separation is expanded to a few inches, and, though very rarely, even to two or three feet; the interval being occupied by clay, either wholly barren, or containing occasionally iron pyrites, or disseminated particles of copper ore, derived from the deposits above.

The metallic deposits, thus described, occur in the blue limestone mass, and terminate in their descent to the southward on reaching the flat bed, never penetrating into the subjacent, siliceous limestone. The galleries, drifts, and sinkings proved this fact. The two former (distinguished in the plan and section by narrow lines) are wholly driven in the blue limestone, the siliceous limestone forming their floor; and in the deep level (marked by broader lines) the siliceous limestone is chiefly cut into. The new engine shaft penetrated 44 feet into the siliceous limestone, and a bore-hole from its bottom went 31½ feet deeper; and a cross-cut was driven from Cock's shaft wholly in the siliceous limestone under the Blue Hole, and connected therewith by a bore-hole; yet by none of these operations was a particle of ore found in this rock.

The experience thus gained prognosticated an early termination to this mining adventure, unless further discoveries could be made either within or beyond the then existing excavations. With the former view, drifts were opened from the Cliff shaft to the north-east and east; and by eight bore-holes the ground was also searched in the south-eastern quarter; but by neither operation was any discovery effected. Galleries were likewise extended to the westward, and by one of these, productive ground was laid open, which led to the excavation of a whole mass of rock, containing disseminated ore, from the flat bed up to the very surface, as indicated by the darker-coloured, triangular space marked on the plan.

To try the ground effectually to the north of the mine, both in the blue limestone and the subjacent siliceous limestone, the following measures were adopted: (See Section.) 1st, A cross-cut was driven twenty fathoms north from No. 8 shaft in the blue limestone, and a winze or pit was then sunk in the siliceous limestone five fathoms deep, from which a bore-hole went five fathoms deeper. 2nd, Another cross-cut went north-west nineteen fathoms, being fifteen fathoms beyond the ore ground, and a bore-hole was put down beyond it. 3rd, A series of bore-holes, thirty in number, were distributed over the north ground, descending in all cases through the blue limestone into the siliceous limestone, and in a few instances perforating the latter rock to the depth of five fathoms. 4th, Trenches were cut down to the blue limestone rock, and extended to the north nearly to the siliceous limestone, which crops out there at the surface. By none of these researches was any discovery made.

I must here observe that had any true lode or rake vein, upon whatever range, existed within the precincts of the mine, it must have been discovered in the course of working; and the same assertion holds good with respect to any vein which might have ranged north and south in the ground, north of the mine; and with regard to any vein upon an east and west range in the north ground, the trenches would have made its discovery. Again, had any irregular metallic deposit,

analogous to those occurring in the existing mine, been contained in the north ground, it must have been detected either by the bore-holes distributed over that surface, or by the trenches.

The preceding details, which may perhaps more immediately interest professed miners, are yet important, since they establish the geological relations of this mine both in a positive and negative manner; and they may thus prove useful to future inquirers in researches of a similar nature.

During the course of operations between May 1827 and May 1829 inclusive, 1529½ tons of ore were raised, averaging in produce 13⅔ per cent. of copper, the sale of which amounted to 18,090*l.* 18*s.* 9*d.*, being equal to 11*l.* 16*s.* 6½*d.* per ton; the average standard price of copper during that time having been about 108*l.* per ton.

In the earlier part of this undertaking the ore raised, amounted sometimes to nearly 100 tons per month; but the last month's work yielded only 29 tons, the main deposits of ore having, in fact, been worked out. These ores consisted chiefly of grey, yellow, and purple sulphurets. Green and blue carbonates and tile copper ores, with small portions of native copper and crystallized red copper ore, occurred much more rarely, having been chiefly found in the part of the blue limestone immediately over the flat bed. Intermingled particles of galena were likewise incidentally met with, as well as blende and iron pyrites more in mass.

This remarkable metallic deposit, coeval in its origin with the limestone rock itself, must have yielded, from first to last, a produce exceeding in value 100,000*l.* sterling.

As dependent on the structure and condition of the limestone rock, I think it necessary to add a few words on the water of this mine. When full access had been obtained to the interior, fissures were found, in general nearly vertical, some upon a north and south, and others upon an east and west range, which, in the course of their extent, varied from the tenth of an inch to four or five feet in breadth, the expansions being sudden, irregular, and of comparatively short continuance. These fissures and cavities are commonly filled with a closely compacted mass of pebbles, gravel, and sand, imbedded in clay, and, when persistent, generally impervious to water; but unoccupied intervals occurring in some places, it is easy to conceive that upon such fissures passing outwardly to the lake, those spaces would become gradually enlarged by the fretting of the lake water, and the feeders of the mine be proportionately increased. Nor was this the only source of the water flowing into the mine. From the horizontal disposition of the flat bed in its direction to the southward, ascertained by the cutting of the deep level, it became evident that the flat bed must run into the lake at the distance of about twenty fathoms from the embankment in the deep water, opposite to Dyer's shaft, the bottom of the lake deepening in that quarter rapidly to the south*. And the surge of the lake, which in a storm is like a tempestuous sea, could not but press its waters with an increased impetus, fretting, by the line of the flat bed, into the mine. And such was found to be the case in the progress of the deep level to the westward.

Thus the discharge of water, from a depth of 9½ fathoms, was, from May to December 1827, 3½ to 4 tons per minute; and afterwards from a depth of 10½ fathoms, between December 1827 and April 1828, 4 to 5½ tons per minute, and in June 6⅓ tons per minute; but after the deep level had passed Spillane's shaft, it increased progressively to 8, 9, 10, and 11⅓ tons per minute. This was caused by the deep level cutting a vertical fissure four inches wide, and by the opening of the flat space between the blue and siliceous limestone, to the height of nine inches. By the latter line great quantities of pebbles were washed into the mine. As a check to the influx of water, dams

* At the distance of 200 fathoms from the embankment, south of Dyer's shaft, the lake has, in fact, acquired the depth of 35 fathoms, which it retains to a considerable extent, the deepest point being 40 fathoms, whence the bottom rises gradually to the opposite shore.

were fixed in the level; but from thenceforward, namely, to May 1829, the average discharge from the mine was 8 or 9 tons per minute. When required, the steam engine (of 36-inches cylinder, working single,) has been made to throw out $13\frac{1}{2}$ tons of water per minute, or nearly 20,000 tons in 24 hours.

(46.) In Crow Island, which is situated about half a mile to the eastward of Ross Island, and is of small extent, being only about twenty fathoms in breadth, the mine is said to have yielded about 100 tons of copper ore of inferior quality. This was obtained from slight, contemporaneous strings, isolated portions and particles of ore, of uncertain distribution in the blue limestone rock, and blended more or less with calcareous spar, and partially contaminated by an intermixture of blende, iron pyrites, and galena; the formation being analogous to that prevailing in the vicinage of the Blue Hole at Ross Island, was poor and unpromising. The principal working was about fifteen fathoms long and six fathoms deep, the line of excavation ranging 30° west of north and east of south, with an inclination of 65° to the south of west.

II.—Carboniferous Series.

I. *In South Munster, viz., in Cork, Limerick, and Kerry.*

Old Red Sandstone.*

(47.) In the eastern quarter of our field, I have first to notice the old red sandstone of Kilworth mountain and the adjacent hills, on the north of the

* I may here remark, that tracts of transition rocks analogous to those described in this paper, (in which conglomerates, sandstone, and quartz-rock, are of such common occurrence,) appear in many cases to have yielded a large proportion of the materials of which the old red sandstone of British geologists is composed. And that the great carboniferous order, or series, forms, in general, an independent and consistent group, appears proved,—1. by the *predominant* unconformity of its position, in relation both to subjacent and superjacent systems; 2. by the general absence of organic remains in the old red sandstone; 3. by the organic reliquiæ peculiar to the carboniferous limestone and the coal formation; and 4. by the not unfrequent interstratification of these three members in the order of succession. Several organic exuviæ, however, being common both to the transition and carboniferous orders, while many are peculiar to either series, affinity as well as difference is thus indicated; but the discordant position of the two systems appears conclusive as to their different eras of production.

Some of the foregoing positions I find entertained also by M. Hoffmann in his *General View of the Geological Relations of the North West of Germany*, 1830. (vid. *Uebersicht 2te Abtheilung*, pp. 503, 504, and 589;—positions which I advanced and partly developed between the years 1818 and 1824 in the *Geological Transactions and Annals of Philosophy*. See in particular the *Annals of Philosophy* for the years 1821, 1822, 1823, and 1824. But I differ from that author in not including, as he does, in the carboniferous series, the red sandstone that is interposed between the coal measures and the magnesian limestone (Zechstein). In this, however, he is not singular, as German geologists in general had, to that date, done the same, comprehending with him under the head of *rothe-todte-liegende* the whole of the carboniferous series, together with the red sandstone subjacent to the magnesian limestone. If the use of the term *rothe-todte-liegende* be still continued, it may be well to restrict it to this red sandstone, lying between the coal forma-

river Blackwater. Furrowed by defiles and ravines whose course is toward the vale of the Blackwater, the subjacent clayslate is exposed to our view, in strata nearly vertical, supporting the sandstone formation in unconformed position. The formation, as here exhibited, may be taken as a good example of the old red sandstone of Ireland, and it will bear a close comparison with that of England, to which it is quite analogous, presenting the same varieties in colour and composition, and consisting of compact and slaty beds of firm sandstone, associated with others of a looser texture, with sandstone conglomerate, and with beds of indurated clay and slaty clay ; the reddish brown colour predominating in the series.

(48.) Within the ranges of the Gaultees, Slievenamuck, Slieve Riagh, and Seefin mountains, clay-slate and greywacke rocks (partially traversed by small veins of calcareous spar) form their foundation, in a position nearly vertical, ranging from the glen of Aharlow to the westward, and upholding on each side unconformable, continuous mountain masses and isolated caps of the old red sandstone formation. An expansion of this sandstone spreads, on the north, into the plains of Limerick, extending westward to, and constituting the substance of, the three ranges of hills called Knockfeernagh, Kilcruaig, with Knockaderry, and Kilmeady ; yet excepting the knoll of Knockfeernagh, which consists of greywacke, and greywacke slate. The sandstone of the plain is generally fine-grained, and yields good flagstones in the quarries adjacent to the road between Kilmallock and Bruff, where it is about three miles wide, nearly horizontal, or gently undulated on the large scale, supporting the carboniferous limestone in conformable position both on its northern and southern sides, and dipping in the former 10° to the north, and in the latter 20° to the south.

In the ranges of Knockfeernagh, Kilcruaig, and Kilmeady, the sandstone is generally composed of granular quartz, with interstices partly filled with white or yellowish earth (like decomposed felspar) or yellow or brown oxide of iron, scales of silvery mica being sparingly scattered through the mass. When the mica is more abundant, the rock takes a coarse slaty structure. When consisting of nearly pure grains of quartz, closely compacted, it approaches to the character of quartz-rock. Though associated with beds of red, indurated clay, and slaty clay, its general colour is yellowish or greyish white ; but where a greater diffusion of iron oxide takes place, it acquires a brownish or reddish tinge. Each range is formed of strata nearly horizontal on the top,

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tion and the magnesian limestone, as is the practice with English geologists, so as to avoid the confusion which has arisen from its extended German signification. On the geological relations of the magnesian limestone, and the subjacent red sandstone in the North of England, compared with their equivalents in Germany, a clear light has been thrown by Professor Sedgwick in his admirable Memoir, published in the Third Volume of the Geological Transactions, Second Series, 1829.

but which on the sides decline toward the limestone plain, under angles varying successively in different quarters from 60° to 40°, 30°, 20°, and even as low as 15° and 10°. The superposition of the limestone to the sandstone may be traced in some places, as at the western ends of the ranges of Kilmeady and Knockaderry; and near the points of contact the limestone is sandy.

Looking to the composition and structure of Knockfeernagh, it may be presumed, that all the three ranges derive their forms from subjacent ridges of greywacke and slate, the sandstone conforming to their surface. In the protruding knoll of Knockfeernagh, the greywacke and slate range to the east and west, dipping 85° to the north; but in the defile below, which traverses the range from north to south, on the east of the knoll, there exposing those rocks, they dip 80° to 85° to the south; the opposite dips doubtless arising from a flexure of the strata in their descent. They are here surmounted by beds of sandstone and red slate-clay in nearly horizontal position. The projecting knoll above is surrounded by the sandstone on every side, and the greywacke and slate which compose it may be described as follows.

A base of clay-slate more or less incorporated with mica, or chlorite, or quartz, and enveloping rounded or angular fragments of hornstone, quartz, and slate; usually containing also, scattered through the mass, scales of silvery mica, particles of vitreous quartz, and more rarely fragments of felspar. Calcareous spar, more or less disseminated, is also not an uncommon ingredient. When in a state of disintegration, the exhibition of yellow and brown oxides of iron becomes very abundant. The same rocks, in the defile below, partake more of the character of a compact clay-slate or novaculite, enveloping some of the other ingredients mentioned. These include a bed of stratified quartz rock, about ten fathoms thick, consisting almost wholly of simple granular quartz-rock, closely consolidated, and exhibiting a small splintery fracture.

(49.) I have already remarked (§. 10. and §. 13.) that in the western quarter of our field, the old red sandstone of Slieve Meesh overlies the transition rocks of Cahirconrée in their range to the eastward; and that they reappear more east from beneath the old red sandstone, forming a low ridge of greywacke, which crosses the river Maine near its head: partly separating the vale of the latter from that of Castle Island, and supporting there, on each side, the carboniferous limestone.

The old red sandstone of Slieve Meesh may be best studied from the northern side, where it is penetrated by deep sinuous glens and ravines. The southern side of the range being little interrupted, does not present the same facilities for observation. Between three and four miles to the south-west of Tralee is the mouth of Curahene glen. At two and four miles east of this, respectively, are the two mouths of Blennerhasset's glen, the more distant being adjacent to the old road leading from Tralee across Slieve Meesh to Castlemaine. Two miles still further east, are ravines adjoining the old road

from Tralee to Killarney. In the last-mentioned locality may be observed alternating beds of red sandstone, red and mottled indurated clay, and red, micaceous, slaty clay. These beds, where exposed in the higher lands, are nearly horizontal, or incline gently to the north; but in descending toward the carboniferous limestone of the vale of Tralee, they successively dip 20°, 15° and 10° north. At the eastern mouth of Blennerhasset's glen are similar beds, inclined 25° to the north. They repose on continuous strata of solid red sandstone, reaching nearly one mile up the glen; but the sandstone gradually loses the intense red colour, becoming generally of a brownish grey hue. The lowest angle observed in the dip of the beds in this glen, was 15° to the north.

The approach to Curahene glen is rendered very striking by the immense accumulation of blocks and boulders of red sandstone and sandstone conglomerate, which form a kind of promontory, proceeding from the mouth of the glen to the plain below, and expanding there to the east and west. Through this accumulation, the stream which issues from the glen, winds its way, having high banks on both sides. In the glen upward, the banks also are composed of similar debris, and the firm rock is first displayed, in any continuity, in the brows overhanging the northern entrance of the glen, where sandstone and sandstone conglomerate dip 30° to the north. Further up the glen these rocks approach nearer to the horizontal position; and still more south, a reversed inclination toward the south becomes perceptible. The sandstone of this glen, whether in situ or detached, is remarkable for its uniform red or purplish colour, with little difference in the shade. It is commonly of a rather coarse structure, and some varieties of the conglomerate contain rounded and angular fragments, chiefly composed of quartz, as large as turkey's eggs.

The beds of red clay and slaty clay, associated with the red sandstone in the northern confines of the formation, appear to decline in their progress westward into the vale, and they probably pass into the sea to the south of Blennerville.

(50.) To the north of Tralee bay, the old red sandstone reappears, forming Kerry Head, and arranged in strata nearly horizontal on the higher lands, but declining thence, on every side, at angles as low as 15° to 10°. In the cliffs along the shore, extending from Ballyheige castle to the westward, and round the Head to the north side, the rocks are well exposed, showing beds of firm sandstone of brown, red, grey, bluish and greenish colours, associated occasionally with beds of red, indurated clay and slaty clay, both simple and micaceous; sandstone conglomerate also occurring in the series.

Carboniferous Limestone.

(51.) This formation is found both in the western and eastern portions of our field, reposing either directly and unconformably on the transition series, or conformably on the old red sandstone, when the latter intervenes.

Thus in the west, at the junction of the valleys of the Laune and the Maine, the limestone rests on the transition rocks; but in its circuitous course eastward up the latter valley, across that of the Brown Flesk, and around, past Castle Island, westward to Tralee bay, it reposes chiefly on the old red sandstone of Slieve Meesh, while to the east it appears resting on the greywacke projection which forms the eastern foot of that range, already noticed in §. 49. North of Slieve Meesh, and south of Tralee, the limestone is slightly inclined to the north, yet gently undulated. North of that town, the strata are more nearly horizontal; but about midway between it and Castle Island, they dip 60° to 65° to the north, forming protruding knolls on a line three miles in extent. Further east, and to the south of Castle Island, and around the greywacke which projects into the vales of the Brown Flesk and the Maine, the limestone is nearly horizontal, yet subject to undulations, as it also is in its further progress down the valley of the Maine, the latter variations in the dip being from north to south; while in the line of contact with the old red sandstone on the south side of Slieve Meesh, the general dip, as exhibited in the quarries, is 20° to 25° to the south. Again, to the north of Ardfert the limestone reposes on the old red sandstone of Kerry Head, while both are overlaid in that quarter by an outlying portion of the coal measures.

It will be hereafter seen, that the limestone of this district, which in its devious course is continued from Tralee bay to Listowel on the north-east, and thence to the mouth of the river Shannon on the north-west, is in conformable position with the superincumbent coal measures, wherever denudation affords an opportunity of observation.

(52.) In the eastern quarter, the carboniferous limestone first appears on the south of the Blackwater in Dromaneen townland, about four miles west from Mallow; and in the Marble-hill quarry the stratification is well displayed, thin beds of black limestone and grey and black slate-clay alternating with each other, the whole dipping 10° to the north; while the greywacke, sandstone, and slate series, which form its southern and western boundary, dip to the south. West of Dromaneen, the greywacke country extends about six miles, before we reach the transition limestone near Roskeen Bridge.

Following the line of the Blackwater to the east, the limestone is found in some parts occupying both banks, and in others confined to one bank of the

river, as may be seen in the map; but the stratification is often ill developed. On the east of Mallow there appears a disposition to the northerly dip. Approaching Fermoy the strata incline toward the south, conformably with the old red sandstone in Kilworth mountain, in which quarter, viz. in the defile called Araglen, may be remarked an outlying portion of the carboniferous limestone, about two miles in extent, the connexion of which with the same formation in the vale of the Blackwater, appears to have been interrupted by denuding causes. Near Lismore the dip is also to the south; but between Cappoquin and Dungarvan bay the strata appear to form an arched inflection from north to south, abrupted at the surface, and hence showing a northern and southern dip on the sides, with nearly vertical strata intervening. In Ballynacourty Point, which forms the northern side of Dungarvan bay, and in the ledge of rocks stretching out eastward into the sea, the limestone strata are arranged according to a semicircular flexure, the dip being successively to the north, the east, and the south. The limestone alternates in some parts with slate clay.

On the other hand, the greywacke and slate ranges, which immediately flank on the north and the south, the vale of Dungarvan, and the line of the Blackwater higher up to the west, generally dip 70° to 75° toward the south.

(53.) In the northern and more central portion of our field, the limestone is supported by the old red sandstone, being inclined, where contiguous to that formation; but in the plains it more nearly approaches to the horizontal position, as at Ballydaniel, two miles north of Broadford, and at Newcastle, in the line of the river Arrow, yet it is subject to local inflections at higher angles, arising from undulations in the strata. The same appearances are observable in proceeding further north toward the Shannon, and north-east toward Limerick.

(54.) The limestone of our tract is frequently continuous over a large area; but, as already shown, it occasionally alternates with slate-clay or shale, as in the central part of the district, at the Broadford quarries, two miles west from Drumcullaghar. It is also associated with lydian stone, hornstone, black carbonaceous shale, trap, and porphyry.

Its association with lydian stone is well developed in the hilly ground adjacent to the south side of the Guestin river, above its confluence with the Launc, containing, as in the Listry quarry, beds of that substance, from a few inches to three and four feet thick. The dip is to the north, while on the opposite side or right bank of the stream, as at Lisinvane, the dip is to the south, the beds consisting chiefly of brown shale, lydian stone, and hornstone, with others of black limestone. This part of the stream appears to run in a concavity formed by an undulation of the strata.

(55.) The association of the limestone with black carbonaceous shale, may be observed to advantage both in the west and east of the field.

In the west, these rocks appear on the coast to the north of the Cashen or Feale river, extending nearly two miles between Ballybunnian and Lick Castle, alternating both in thin and very thick beds, whose general inclination is toward the north-east, yet undulated on the large scale, commonly under an angle of 25° to 30°, but in some places they are at high angles, and even vertical. These great undulations have been broken in upon, by inroads of the sea in a direction from west to east, forming six or seven inlets or coves, in which, by abruption and perforation, the rocks have been wrought into a variety of fantastic forms, with archways and caverns winding into the interior. In the black shale, iron pyrites being incidentally disseminated, and mutual decomposition taking place, alum, hydrate of iron, &c. are produced, and the face of the rock becomes stained with white, yellow, brown, and reddish depositions. These substances penetrate also into the fissures of the rock, in which wavellite likewise is found.

In the east we may notice that portion of the carboniferous limestone which is adjacent to the angular boundary, formed by the conjunction of the counties of Cork, Limerick, and Tipperary. It there contains massy beds, both of grey slate-clay and black carbonaceous shale, in the latter of which iron pyrites is not unfrequently distributed. The appearance of this black shale gave rise to trials for coal about forty years since, several pits having been sunk for that purpose, but without any success.

(56.) The association of the carboniferous limestone with trap and porphyry, has been treated by me, at some length, in my Memoir on the East of Ireland*, and I therein indicated (§. 178.) that the distribution of those rocks in the limestone, was probably more extensive than I had then an opportunity of ascertaining. The subject has since been resumed, both by Dr. Apjohn† and Mr. Ainsworth‡, and to the respective memoirs of those gentlemen I beg to refer for the details of their extended researches. With Captain Sabine, R.A., and Mr. Ainsworth, I have since had the satisfaction of visiting part of the ground formerly left by me unexplored; and in the map I have introduced the range of the trappean and porphyritic series determined by the latter. Of that portion of the district which lies to the west and north-west of the field formerly examined by me, a general view may be obtained from the hill of Carrig Parsons, situated about midway between Limerick and Pallis Hill, overlooking the vale which extends to the foot of the Bilboa mountains on the north.

* Geol. Trans., First Series, Vol. 5.

† Journal of the Geological Society of Dublin, No. 1.

‡ Ibid., No. 2.

The hill is composed of limestone, and the strata are curved from south to north, but the crown of the arch is ruptured, the line of fracture being from south-west to north-east, and the beds basset out on the opposite sides of the rupture under an angle of 30°, in the western part of the hill dipping toward the vale, and in the eastern from the vale. The strata in the eastern part of the rupture present a bluff toward the valley, which is on a line with the bluff of Knockeen limestone hill, distant a few miles on the east, while still further east, on the same line, appears the trap bluff or precipice of Pallis Hill, impending over Linfield. As viewed from the summit of Carrig Parsons, the trap ranges are most prominent on the south-east near Pallis Hill; thence receding toward the south and west, through the Cahirconlish, Carrigfeoch, Ballochbega, Ballinaguard, Knocknea, and Cahirnarry ranges; while to the north-west, and more insulated, rise the trap hills of Carrig O'Gunnel, adjacent to the Shannon; and to the west of north appears the insulated trap range of Newcastle, which, in its extension west, approaches within a short distance of the artillery barracks at Limerick. In the series of such of these trap and porphyry rocks as have come under my view, I have not succeeded in finding the stilbite, mesotype, and olivine, which Mr. Ainsworth states he had noticed.

I shall here merely add a few remarks on the trap formation at Carrig O'Gunnel, Knocknea, Cahirnarry, and the porphyry south of Lough Gur.

The castle of Carrig O'Gunnel is built on a protruding mass of trap conglomerate, amorphous, and irregularly traversed by fissures.

The paste of the conglomerate is chiefly compact felspar, variously coloured, and sometimes mottled, but most commonly of a reddish hue, apparently much charged with iron; but in some places it consists of very fine-grained, compact greenstone. The base envelopes fragments of limestone, mostly angular, sometimes as large as the head, and even larger, also fragments of trap corresponding more or less in composition with the paste. Among these may be noticed also basalt with shining facets of small and minute grain. In the trap, calcareous spar appears as the most common ingredient, and portions of green earth are also incidentally diffused. Where the calcareous spar has decayed, the rock is porous and vesicular. To the north of Castle Carrig O'Gunnel hill, is a lower hill, which consists of calcareous conglomerate, a base of limestone with some green earth diffused, inclosing numerous fragments of trap. In these conglomerates occur numerous crinoidal remains; also broken bivalves; and I noticed one specimen of Cyathophyllum.

The trap conglomerate of Knocknea resembles in many respects that of Carrig O'Gunnel, but it is disposed in tabular masses, nearly horizontal, dipping only a few degrees to the north-east. A defile separates this hill from that of Cahirnarry, on the north. The latter consists of compact basaltic greenstone, containing acicular crystals of glassy felspar, and grains of hornblende or augite, and it is disposed in a rudely thick, columnar form, without distinct sides. To the north-east of Cahirnarry is a lower hill, which appears

chiefly composed of flat tabular masses of trap conglomerate (enveloping, as usual, fragments of limestone), and generally of a greenish colour, from the intimate diffusion of green earth in its composition. To the east of this, and about one mile from Cahirnarry trap hill, is the limestone hill of Carrig Parsons, which I have already mentioned.

There are few parts of the trap district in which the red felspar porphyry, is better developed than in a hill called Knock Derg, situated to the south of Lough Gur.

The basis is chiefly a finely granular or compact felspar, containing crystals of glassy felspar; the whole being, where the rock is fresh or not weathered, of a deep flesh colour or reddish brown, or of a brownish red cast. When much disintegrated, the stone, at the first glance, looks like a dirty or brick-red sandstone. The porphyry, however, is not uniformly red or brown, being in some places striped or mottled with disseminated portions of green earth. The mass of the rock is formed occasionally of spheroidal or ovoidal concretions, which separate by atmospheric influences into concentric layers. Toward the northern foot of the hill green-coloured trap conglomerate also occurs.

It is much to be wished that some one, possessed of the necessary leisure and gifted with sufficient devotion, would construct an exact topographical map of the Limerick district occupied by trap and porphyry, showing in all cases, by the aid of sections, the precise relations of these rocks to the limestone with which they are there associated.

(57.) Large tracts of the limestone field may be traversed without encountering more than a few, thinly scattered, organic remains. It is from local deposits met with incidentally, that they are chiefly to be procured. One of the most productive is in the valley of the Maine, in the Ardconnaught quarries, and adjacent to Castlemaine mine. The following is a list of those I procured in that quarter; and the fossilist will readily notice that while most of the organic remains enumerated, are of common occurrence in the carboniferous limestone of other countries, several are also found in transition tracts, some of which have hitherto been considered as distinctive of the transition period: to these I have prefixed the mark, §.

But to such as have hitherto been noticed only in the Cork transition limestone, and not in other transition tracts, I have affixed the mark (c.) The signs † ‡ have the same import as was explained in §§. 13 and 33.

Crustacea:

§ Calymene concinna, (Dalman, Tab. I. fig. 5.)[1], besides fragments of one or two indeterminate species of Trilobite.

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[1] Om Palæaderna eller de sä kallade Trilobiterna af J. W. Dalman. Ur K. Vet. Acad. Handlingar, 1826. Stockholm, 1827.

Cephalopoda polythalamia:

§ Orthoceras striatum, (Sow. T. 58.) †.
O. undulatum, (Sow. T. 59.) ‡.
O. unguis ‡, (Phillips, Plate XXI. fig. 2.)[1]
Nautilus globatus, (Sow. T. 481.) †‡.
N. multicarinatus, (Sow. T. 482. fig. 1, 2.) c. ‡.
N. ovatus, (Ellipsolites of Sow. T. 37.) †.
A Goniatite also occurs. The *Orthoceras striatum* appears very frequently, sometimes exceeding two feet in length, and five and a half inches in diameter at the larger end.

Cephalopoda monothalamia:

Bellerophon tenuifascia, (Sow. T. 470. fig. 2, 3.) †‡.

Gasteropoda:

Euomphalus catillus, (Sow. T. 45. fig. 3. 4.) †‡.
Pileopsis vetusta, (Sow. T. 607. fig. 1 to 3.) †‡.
Ampullaria helicoides, (Sow. T. 522. fig. 2.) c. ‡.
Cirrus acutus, (Sow. T. 141.) †‡.
Melania constricta (Sow. T. 218. fig. 2, and Phil., Pl. XVI. fig. 1.) ‡.
M. tumida, (Phil., Pl. XVI. fig. 2.) ‡, and another species of Melania or Turritella undetermined.
Natica ampliata, (Phil., Pl. XIV. fig. 21 and 24.) ‡, and one other turbinated shell less distinct.

Conchifera:

The prevailing species are referable to the genera Producta, Spirifera, and Terebratula: viz.
Producta scotica, (Sow. T. 69. fig. 3.) †‡.
P. Martini, (Sow. T. 317. fig. 2, 3, 4.) c. ‡.
P. concinna, (Sow. T. 318. fig. 1.) c. ‡.
P. lobata, (Sow. T. 318. fig. 2 to 6.) c. ‡.
P. punctata, (Sow. T. 323.) c. ‡.
P. fimbriata, (Sow. T. 459.) ‡.
P. analoga, (Phil., Pl. VII. fig. 10.) ‡, and two other species of Producta not yet named.
Spirifera cuspidata, (Sow. T. 120.) †‡.
S. striata, (Sow. T. 270.) †‡.
S. pinguis, (Sow. T. 271.) †‡.
S. octoplicata, (Sow. T. 562. fig. 2 to 4.) †‡.
S. resupinata, (Terebratula, Sow. T. 325.) c. ‡.
S. glabra, (Sow. T. 269. fig. 1.) †‡.
S. obtusa, (Sow. T. 269. fig. 2.) †‡.
} Considered as one species by Professor Phillips.
S. attenuata, (Sow. T. 493.) †‡.
S. bisulcata, (Sow. T. 494. fig. 1, 2.) ‡.
S. squamosa, (Phil., Pl. X. fig. 21.) ‡.
S. semicircularis, (Phil., Pl. IX. fig. 15, 16.) ‡.
S. glabristria, (Phil., Pl. X. fig. 19.) ‡.
S. expansa, (Phil., Pl. X. fig. 18.) ‡.

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[1] See the very valuable and elaborate Illustrations of the Geology of Yorkshire, by Professor Phillips, Part II. Mountain Limestone District.

Conchifera: (continued)

Spirifera rhomboidea, (Phil., Pl. IX. fig. 8, 9.) ‡.

S. insculpta, (Phil., Pl. IX. fig. 2, 3.) ‡, besides three species of Spirifera not yet named.

Terebratula crumena, (Sow. T. 83. fig. 2, 3.) †‡.

T. cordiformis, (Sow. 495. fig. 2, 4.) c.

T. pugnus, (Sow. 497.) †‡.

T. pleurodon, (Phil., Pl. XII. fig. 25, 26, 27.) ‡.

T. radialis, (Phil., Plate XII. fig. 40, 41.) ‡; besides several other Terebratulæ, some of which appear referable to—

T. elongata, (Schlotheim, T. 20. fig. 2.) †. } Considered as the same species by Von Buch.
T. lata, (Schlot. T. 20. fig. 3.) †. } (See p. 100, über die Terebrateln.)

T. rostrata? (Schlot. T. 16. fig. 4.) †, Spirifera.

T. lævigata, (Schlot. T. 18. fig. 1.) †‡, Spirifera; seems more nearly allied to *Spirifera glabra* than to *S. oblata* of Sowerby.

But these are severally given by that author as derived from transition tracts on the Continent[1].

Among the *Bivalves* are also to be noticed,

Isocardia vetusta (Phillips), the upper valve of a Posidonia (Phillips).

Pleurorhynchus elongatus, (Phil., Pl. V. fig. 28. Cardium, Sow. T. 82. fig. 2.) ‡.

P. hibernicus (Phil. Cardium hibernicum, Sow. T. 82. fig. 1. 3.) c.‡.

Pecten plicatus (Sow. T. 574. fig. 3. and Phil., Pl. VI. fig. 21.).

P. dissimilis (Phil., Pl. VI. fig. 19.) ‡, and three other species of Pecten not yet named, besides an Avicula, and some other bivalves as yet undetermined.

Of *Polyparia*, remains chiefly referable to the genera Retepora, Cyathophyllum, Favosites, Turbinolia, and Astrea. But the *Amplexus coralloides* is not of uncommon occurrence. The *Retepora membranacea* (Phil., Pl. I. fig. 1 to 6) is also common, spread in wide sheets through the rock.

Of *Crinoidea*, the remains which have principally occurred to me belong to portions of vertebral columns, which appear referable to—

§ Actinocrinites moniliformis, A. triaconta-dactylus, Cyathocrinites tuberculatus, and Platycrinites lævis. (See Miller's Crinoidea.)

Some of the preceding organic exuviæ I have noticed also in the quarries adjacent to Castle Island, associated with others not remarked on the line of the Maine, e. g. *Orthoceras striatum, Nautilus ovatus; Euomphalus catillus; Melania constricta; Producta Martini, P. punctata; Spirifera imbricata* (Tereb., Sow. T. 334. fig. 3, 4.) ‡, *S. lineata* (Tereb., Sow. T. 334. fig. 1, 2.) ‡, *S. striata, S. obtusa, S. attenuata; Terebratula hastata* (Sow. T. 446. fig. 2, 3.) c.‡, *T. pugnus, T. pleurodon; Pleurorhynchus elongatus, Pleurotomaria carinata*? (Phil., Pl. XV. fig. 1. Helix, Sow. T. 10.) ‡, and an Orbicula? *Amplexus coralloides, Favosites*, and *Retepora;* and also a fragment of the abdomen of a Trilobite. Several of these remains I have observed likewise in the carboniferous limestone adjacent to Newcastle, on the north-eastern side of the South Munster coal tract.

In further illustration of this subject, I here add a list of the species remarked by Mr. S. Wright in the carboniferous limestone, with which he has favoured me, mostly determined by Mr. Sowerby.

	Locality.
Nautilus biangulatus, (Sow. T. 458. fig. 2.) ‡....	Buttevant, and Glen of Ballybeg, in the county of Cork.

[1] Nachträge zur Petrefactenkunde.

	Locality.
Nautilus sulcatus?	Buttevant, and Glen of Ballybeg, in the county of Cork.
N. a large species undetermined	Castle Connell, co. of Limerick.
Bellerophon, a large species undetermined	County of Clare, north of Limerick city.
Euomphalus pentangulatus, (Sow. T. 45. fig. 1, 2.) †‡	Castle Connell.
E. catillus, (Sow. T. 45. figs. 3, 4.) †‡.....	ditto.
Ampullaria nobilis, (Sow. T. 522. fig. 1.) ‡.....	ditto.
A. helicoides, (Sow. T. 522. fig. 2.) c. ‡.....	Buttevant.
Producta hemisphærica, (Sow. T. 328.) †‡	ditto.
Spirifera bisulcata, (Sow. T. 494. fig. 1, 2.) ‡	ditto.
S. glabra, (Sow. T. 269. fig. 1.)	†‡ Castle Connell.
S. obtusa, (Sow. T. 269. fig. 2.)	
S. oblata, (Sow. T. 268.) †‡.....	ditto.
S. lineata, (Terebratula, Sow. T. 334. fig. 1, 2.) ‡	ditto.
S. imbricata, (Tereb. Sow. T. 334. fig. 3, 4.) ‡	ditto.
S. trigonalis, (Sow. T. 265.) c. ‡	Clonmell.
S. attenuata, (Sow. T. 493.) †‡	ditto.
§ Terebratula affinis, (Sow. T. 324. fig. 3.).....	†‡ Buttevant.
T. prisca, (Schlot. T. 17. fig. 2.)	
T. sacculus, (Sow. T. 446. fig. 1.) †‡	Castle Connell.
T. pugnus, (Sow. T. 497.) †‡	ditto.
T. biplicata, (Sow. T. 437. fig. 2, 3.)	ditto.
T. indentata (Sow. T. 445. fig. 2.) ‡	ditto.
Pleurorhynchus hibernicus	ditto.
Cyathophyllum and Tubipora	ditto.

I learn also from Lieut. Weller and Capt. Sheppard, of the R.A., that they have found the following organic remains in the carboniferous limestone of the county of Clare, namely, north of the Shannon, at the distance of three and five miles respectively from the city of Limerick: Trilobites, Orthoceratites, *Pleurorhynchus hibernicus*, Spiriferæ, Productæ, Euomphalus, and Retepora, with several species of Crinoidea, the *Ampullaria helicoides*, and a Natica; and in the limestone south of the Shannon, near Limerick, also a few specimens of univalve shells. Of the Trilobites, the post-abdominal portions of six individuals only were met with, which belong to two species; one of which appears to be new or undescribed, and the other to bear some affinity to the Trilobite figured by Martin under the name of *Entomolithus oniscites*, in tab. 45*, fig. 1.[1]

Coal Formation.

(58.) The South Munster coal tract occupies a large area, computed to contain nearly one thousand square miles; yet the seams of coal which have been met with, are comparatively few in number and importance. Nor is it likely that many exist, for the elevated position of the coal-field above the

[1] See *Petrificata Derbiensia.*

adjacent limestone plains; the rivers which intersect it east, south, and west; the roads which traverse it in various directions; the ravines which furrow its escarpments, and the limestone knolls which protrude within its area, afford such means of observation that many valuable beds of coal could scarcely have escaped detection. In fact, the more important appear confined to a small district lying north of the river Blackwater and south-west of Kanturk.

I propose, in the first place, to trace the contact of the limestone with the coal rocks around the border and in the interior, and then to give a general view of the position of the coal measures in different parts of the tract; concluding with further notices of their composition and structure, and of the coal mines hitherto wrought.

(59.) In making the circuit of the South Munster coal tract, the carboniferous limestone, wherever apparent, is almost invariably found following the foot of the hills, seldom rising up a small portion of the escarpment; and when it does, the position appears to proceed from an undulation in the beds.

The following observations show the corresponding dips of the limestone and the superjacent coal measures, on the western and eastern sides of this coal-field.

In the West, on the Ballybunian coast (§. 55.), the ascending order of succession is from limestone to shale, and from shale to sandstone. The shale first intercepts, at intervals, a solitary bed of sandstone; but in proceeding north-east sandstone gradually becomes predominant, as in the headland at Lick Castle, where these beds, with slight interposed layers of shale, dip 30° to the north-east; and this arrangement is traceable in ravines to the hilly range of Knockanore, on the east[1]. In proceeding, however, further east toward Listowel, the beds, both of the limestone and the coal rocks, approach the horizontal position, e. g. in the banks of the river Feale to the east of that town, dipping there only 5° to the south-east.

	The limestone and coal measures dip
In the northern side of the ridge, on the south-west of Ardfert, and within three miles of the town ..	20° to 25° to the southward.
While in the southern side of that ridge and north of Tralee they incline gently to the.....	northward.
North-eastward of Castle Island	30° north-eastward.
East of ditto.....horizontal or 10° to 15°	eastward.
South of ditto, at Dicksgrove, beyond the Brown Flesk.....	40° to 50° southward.

[1] From this headland we perceive with the naked eye that the position of the coal rocks near Kilcordan lighthouse, on the opposite coast, in the county of Clare, corresponds with that of the beds under Lick Castle, dipping likewise to the north-east.

	The limestone and coal measures dip	
In the quarries extending toward Milltown on the south-west	20° to 40°	southward.
Between the valleys of the Maine and the Guestin, undulated from north to south and from horizontal to	40° and 50°	north and south.
On the East of the coal tract, and proceeding from north to south.		
At Parkmore and Shrewlana, north of Shanagolden	10° to 15°	north-west.
At Drumruagh, about five miles south of Newcastle	10° to 15°	south-west.
At Broadford, two miles west from Drumcullaghar	35°	south-west.
In the line of the Awenbeg river at Liscarol, the limestone forms an inlet, an arched inflection from south to north, abrupted at the surface, bounded by and supporting the coal measures on the north, west, and south, in conformable position, under angles varying from horizontal to	40° and 50°	north, west, & south.
In the escarpment toward Kanturk, successively	50°, 45°, 20°	south.
To the east of Kanturk	30°	south-west.
North of the tongue of coal measures stretching east toward Doneraile the stratification of the limestone is not well displayed; but the coal measures there visible form an arched curvature from north to south, abrupted at the surface, beyond which inflection, proceeding toward Mallow, their general dip is	45° to 20°	south.

(60.) Within the interior of the coal tract the carboniferous limestone appears in knolls, protruding through the coal measures at Maaling, Tour and Skull, and at Carrigdulkeen.

At Maaling, situated near the left bank of one of the tributaries of the river Allow, and north-east from Newmarket, the limestone rises to the surface in two places on the higher grounds, disposed in strata flatly undulated from north to south, and supporting the coal rocks in corresponding position. It is traceable to the left bank of the river, and again in the more elevated lands about two miles to the westward. At Maaling the limestone, where quarried, is continuous, and of a black colour, containing courses of nodules of lydian stone which extend about twenty feet in depth, but from which the subjacent strata are free. In the latter is a bed one foot thick, almost composed of lithodendra.

Tour Hill lies about six miles west from Maaling, and to the north-west of Newmarket, forming high ground, 1329 feet above the sea. The limestone here rises in dome-shaped strata, supporting the coal rocks, which latter constitute the summit of the hill in the form of a cap, as well as the external border of the limestone, all being in conformable position. The limestone

strata are continuous, 2 to $3\frac{1}{2}$ feet thick, bluish or blackish grey, dipping to all points of the compass 25° to 30°, and containing lydian stone in beds, veins, and intermingled portions. The limestone reappears in the vale at the eastern foot of Tour Hill, and again at Skull, beyond the vale, about one mile distant, in a direction to the north of east, and in strata nearly horizontal. In these lower positions the limestone is purer, being less contaminated with siliceous matter. In the Tour limestone organic remains are sparingly found, being chiefly fragments of Crinoidea and *Producta Martini*, but the *Sanguinolaria concentrica* (Phillips) also occurs.

Another outbreak of the limestone occurs at Carrigdulkeen, about ten miles to the south-east of Castle Island, and within two miles of the right bank of the river Blackwater. The deeper strata appear to be nearly horizontal, but in the higher grounds the dip is 20° to 30° to the south, and the nearest superjacent coal rocks dip in the same manner. This limestone is nearly in an alignment with that of the Guestin stream situated to the west.

(61.) The coal rocks vary in position in different portions of the tract. On the north coast, extending toward Shanagolden and Fynes Island, they may be considered as mainly undulated from the north-east or easterly inclination to the south-west or westerly, both the convex and concave portions being nearly horizontal where perfect, while the ascending or descending beds rarely attain an elevation exceeding 40° or 50°. But all these beds are commonly more or less abrupted at the surface, as well as in other portions of the tract.

The undulated structure is also apparent on the line between Newcastle and Castle Island, passing through Abbeyfeale; the coal rocks dipping in the northern escarpment 40° to 20° to the south-west, and in the southern 30° to 10° to the north-east.

The arrangement between Broadford and Kanturk, passing through Freemount and Newmarket, is analogous, the prevailing undulations being from north to south, yet in some cases attaining as high an angle as 80°.

In penetrating from the westward, from Castle Island to Carrigdulkeen, we find the coal measures, where in contact with the limestone at the foot of the escarpment, slightly inclining to the south-east, but in the interior becoming gradually elevated to an angle of 45°, dipping south-east, as at Scartaglen, adjoining the Brown Flesk. Beyond that river they become nearly horizontal, then gently undulated, and at Carrigdulkeen they correspond in position with the subjacent limestone.

In crossing from the valley of the Maine to the river Guestin in Barry's glen, the dip is first successively 40° and 60° south; it then gradually declines to

the horizontal, and is afterwards 8° or 10° to the north; while further on in Barry's glen, the southerly dip is resumed at angles between 40° and 20°. But in the range of hills lying between that glen and Killarney the interchangeable dip is repeated, at high angles, vertical beds intervening.

A similar structure is observable, in the same parallel, in the eastern portion of the tract. Thus, immediately north and west of Kanturk, the beds undulate from north to south, their curvature seldom reaching to a high angle; but between the Brogeen stream (which joins the Allow river from the west, near to Kanturk) and the Blackwater on the south, the coal rocks are generally in a position approaching to the vertical, with dips interchangeable north and south.

The southern portion of our coal-field, is thus marked by a range of nearly vertical beds, extending from the northern side of the Laune and Killarney on the west, to the banks of the river Allow on the east. On the south, this range immediately conjoins with the transition rocks, and it is remarkable that on the greater part of this line, namely, by the course of the Blackwater, the two series are found, the former on the left and the latter on the right bank of that river, both dipping to the southward, and at angles nearly corresponding, viz. between 75° and 45° south, which led me in the first instance, combined with other considerations, to conceive the formations contemporaneous; but this idea was dispelled on finding the coal measures in the western and eastern portions of the tract directly incumbent on the carboniferous limestone, and the latter in the west reposing, in part, on the old red sandstone.

(62.) The rocks of the South Munster coal-field consist chiefly of varieties of sandstone or gritstone, and slate or shale, alternating with each other. In this series, I have not met with coarse conglomerates; and the slaty micaceous sandstone or flagstone, which is extensively developed in the coal formation of the county of Clare (as well as in parts of that of Leinster), appears generally deficient in the tract, south of the Shannon.

In the line of contact with the subjacent limestone, brown, yellow, grey, and black shales are the more common rocks. When firm and intermingled with quartzose and micaceous matter, they partly resemble some kinds of greywacke slate. The line of cleavage in the shales commonly forms a highly oblique angle with the plane of stratification; and on exposure to meteoric influences, the stone generally shivers into long splinters or spicular fragments. In some of the beds may also be observed a tendency to spheroidal concretions, composed of concentric lamellæ, formed of very fine-grained, micaceous gritstone cemented by ferruginous shale. Portions of the black shales are in some places employed as black chalk.

The *gritstones* are most commonly of brownish or greyish hues, seldomer greenish, and are more or less argillaceous or siliceous, as slaty or quartzose matter prevails in the composition, being also more or less micaceous. Some of the argillaceous gritstones, when containing small scaly frag-

ments of slate interspersed, resemble some kinds of greywacke; and the purer quartzose varieties approach, in places, to the character of granular and splintery quartz rock. The gritstones generally form hard compact rocks of fine grain, quartz with more or less mica being the principal constituents, and the cementing matter forming the least proportion.

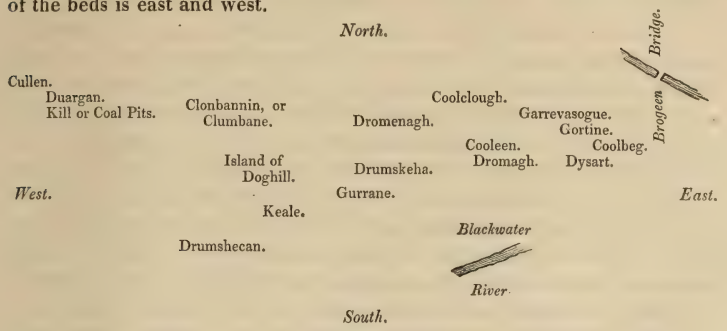
(63.) The coal of Munster, as of Leinster, is wholly anthracitous. In the field under consideration, it is found in beds either of pure anthracite, possessing a strong lustre and a conchoidal fracture, and is easily frangible; or in thin slaty, tender, and flaky layers, generally associated with black carbonaceous shale. A portion of a bed of the latter, is sometimes so strongly charged with carbon, as to burn limestone very well; though in the fracture, the grain of the shale appears wholly dull and earthy; e. g. at Tullig culm pits, situated to the north of Abbey-feale. But in no part of the tract, have I seen coal so firm and solid, as that which occurs in the Leinster districts, where it is raised in blocks, hard and tenacious. In South Munster it is generally fragile, and hence brought to the surface in the form of small coal, bearing the common name of *culm*. The coal is also usually much contaminated with iron pyrites, though beds do occur, comparatively free from that substance, being then denominated *sweet* coal.

(64.) With the exception of the small district on the south-west of Kanturk, the beds of coal met with throughout the tract are unimportant, their average thickness varying from less than one foot to between one and two feet, including the black shale with which the coal is partially interlaminated, and which in some places constitutes the greater portion. Coal thus interlaminated with shale, has been met with in the hills north of Killarney and Tralee, but in no case was it found worthy of pursuit. The grey shale which there accompanies the coal, contains in some places small, isolated, elliptical nodules of clay ironstone.

Culm is raised from analogous beds at Loughill, nine miles north-east of Tarbert, on the left bank of the Shannon, and also three or four miles to the north of Abbeyfeale. At Tullig the slaty culm seam, is fifteen to twenty-four inches thick, the floor being black shale, and the roof gritstone, all dipping about 30° to the south-west. In Barna or Sugar Hill, which is situated nearer to the north-eastern escarpment of the coal country, is a bed of good flaky anthracite, from nine to twelve inches thick. In a more central portion of the tract, Mr. Griffith, in the year 1833 or 1834, discovered a bed of culm, in forming the new line of road from Newmarket to Castle Island, through the Crown lands of Pobble O'Keefe. A culm bed is said to have been found likewise toward the south-western escarpment, about three miles to the north of Castle Island. Slight indications of culm have been noticed also in other portions of the tract; as in the tongue of coal rocks which extend from the west and north of Mallow toward Doneraile; but the trials were not productive.

(65.) The district which claims our chief attention, extends between seven and eight miles in an eastern and western direction, with an extreme breadth

of four to five miles, and is situated south-west of Kanturk and north of the Blackwater, its eastern extremity being about one mile west of the river Allow. The northern boundary may be considered as ranging from the townland of Garrevasogue, on the east, to that of Cullen, on the west, while the southern boundary passes through the townland of Drumshecan. The annexed diagram will convey a general idea of the relative position of the properties through which this coal deposit is distributed. The general range of the beds is east and west.



On the west the townlands of Cullen, Duargan, and Kil belong to Counsellor N. P. Leader, as also on the east those of Cooleen, Dromagh, Dysart, Coolbeg, Gortine, and Garrevasogue. To Major Freeman belong Clonbannin and Island of Doghill; to Mr. John Leader, Keale; to Mr. Broderick, Drumshecan; to Mr. Wallis, Gurrane; to Mr. Dennis O'Callaghan, Drumskeha; to Mr. Morrison, Dromenagh; and to Mr. Walcot, Coolclough.

The more valuable portion of the district appears to be that which ranges from Gortine on the east, through Dromagh, into Drumskeha on the west, being that in which the main, or *bulk* beds, as they are termed, are particularly found. In the other collieries the culm seams are, with few exceptions from twelve to eighteen inches only in thickness, and I have been informed most of the parties engaged in working these small seams, have derived little advantage, while others have lost by the enterprise.

The field has been chiefly opened, in the eastern quarter, by three levels, one of which is conducted into Coolclough, from the south to the north, about eight hundred yards in length, cutting the coal at the depth of forty yards, which there consists of three seams, all dipping south, the two northern at a high angle, the southern at one rather lower. The distance between the northern and middle seam, is twenty-seven yards, and between the latter and the southern, sixty yards. In all three the floor or seat is gritstone, and the roof shale, and the coal is commonly two to three feet thick, but in some places compressed to eighteen inches, and in others enlarged to fifteen feet.

Another level was brought up from south to north, namely, from the vicinity of the Blackwater into the western part of Dromagh, being about one mile in length.

The beds thus cut through, show repeated interchanges of dip from south to north, with vertical strata intervening between each change of dip, the coal seams conforming to this arrangement, as illustrated in Section No. 6. Plate I. This section was constructed for the service of Mr. Leader by Mr. Griffith, and for a copy of it, I am indebted to the former gentleman. On the south, the beds dip about 45° to the southward, but in proceeding northward, they gradually become vertical, then incline northward, are again vertical, and afterwards the southerly dip is resumed. This succession is repeated in the more northern part of the section. It will be seen, that in the line of this level, eighteen small seams of culm were intersected before the four main or *bulk* beds, and the four other seams north of them, were met with. It will also be observed, that in the northern part of the section, the flexure of one coal bed is perfect in its changeable dip from south to north; from which consideration, and the general structure of the country, it might be inferred, that many of the coal beds may converge in depth, thus reducing considerably the actual number of the seams. It must be left to future experience, however, to determine, whether these beds are generally continuous in depth. I observed in one part of the field a thin bed of black shale dipping 80° north, which in its ascent thinned out, and did not reach the surface; and a similar discontinuance might occur to a bed in its descent.

The bulk beds of culm extend in width from two or three feet, to ten, fifteen, and twenty feet, according as the walls are expanded or contracted; but the bulks occur only at intervals, there being intervening distances void of culm, in which the walls of the bed are drawn nearly close together. These bulks, therefore, are arranged somewhat in the form of parallel pipes, descending into the earth; and yet in this descent, they are subject to contractions also.

This level has been extended to the eastward on the main beds, namely, those called the bulk, the rock, and the coal veins, about two miles in length, obtaining at the eastern extremity a depth of forty yards below the surface. The workings on coal are conducted above that level, and it is only in a few places, that trials on the coal have been made forty yards deeper, Mr. Leader leaving all below that level, as a reserve for a future period, when, with the aid of deeper shafts and of steam engines, his collieries may be wrought on a more extended scale.

Faults occasionally traverse the coal-field, ranging north and south, shifting the beds to the north three or four yards, and in some places as much as fourteen or fifteen yards. Of the greater dislocations, three or four parallel ones occur in Dromagh and Gortine.

In the Dromagh section, it may be seen, that in the great majority of instances,

the floor of the coal is black shale, and the roof slate-clay or sandy slate; but there are a few cases in which the floor is slate-clay or sandy slate, and the roof is either black shale or gritstone.

A third level was brought up, also from the south, into Dromenagh, about seven hundred yards in length, cutting the coal at the depth of thirty yards from the surface.

Here are four coal seams, each about one foot thick, composed of conchoidal anthracite, the intervening coal measures being respectively sixty to seventy yards thick, and all dipping about 60° to the south. The floor of all these seams is black shale, and the roof gritstone. The beds of coal wrought in Clonbannin and Kil, are said to be the western extension of those of Dromenagh. To the north of Dromenagh, approaching the Brogeen river, the gritstone dips 80° to the south.

In the Island of Doghill the floor of the coal also is black shale, and the roof gritstone, and the dip south.

In Gurrane the coal seam is one to two feet thick, the floor being gritstone, and the roof black shale two feet thick, over which lie grey sandy slate three feet, gritstone two feet; then slate again, &c., all dipping 70° to the south.

In the shale of this district may occasionally be observed small nodules, and even thin discontinuous layers of clay ironstone; but the ore does not appear to be at all abundantly distributed, either in this or any other portion of the South Munster coal tract.

The preceding notices may suffice to convey an idea of the general structure of this field, in which no excavations have hitherto been made to a greater depth than eighty yards from the surface.

(66.) The considerable quantities of iron pyrites which sometimes accompany the coal, are in places impressed with plants, and the coal itself seems, in a great measure, composed of a congeries of vegetables. The impressions occur also both in the dark and light-coloured shales, and in the clay-ironstone. The vegetable remains to be obtained from the refuse of the coal-pits, appear chiefly assignable to Equiseta, Calamites, Filices, Lepidodendra, Stigmariæ, and Sigillariæ, besides numerous impressions of indistinct reed-like plants and grasses. Compressed stems of Stigmariæ ten or twelve yards in length sometimes occur in the black shale, also partially flattened trunks of Calamites. Of the latter, I have a fragment, measuring in the transverse section, eleven inches by eight inches; but the colliers assured me, they were sometimes found as large as eighteen inches by twelve inches. In the Stigmariæ, Sigillariæ, and Calamites, the external coating consists of coaly matter, while the interior is fine-grained gritstone.

In looking over, with Professor Phillips, such specimens as I was able to procure and bring away with me, the most distinct appeared referable to

Pecopteris. { Two species apparently undescribed } by Sternberg, (*Flora der Vorwelt*); Ad. Brongniart, (*Végétaux Fossiles*); or Lindley and Hutton, (*Fossil Flora of Great Britain.*)

Lepidodendron erosum. Lindley and Hutton, Pl. 7. fig. 1.
Impressions of Lepidodendra and their leaves.
Asterophyllites longifolia. Lindley and Hutton, Pl. 18.
Stigmaria ficoides. Ibid., Pl. 31 to 36.
Sigillaria, apparently undescribed.
Bechera grandis? Pl. 19. fig. 1. Lindley and Hutton.
Sphenophyllum Schlotheimii. Pl. 27. Ditto.

The colliers stated also, that in a few places shells have been found in the shale, but that, from their perishable nature, they soon wasted away on exposure to the atmosphere. Two such beds are indicated in the Dromagh section, (Plate. I. fig. 6.) under the name of "muscle slate." I had not, however, the good fortune to find any of these shells, as few pits were at work during my different visits to this district. But in the black shale of Ardnagragh, situated about three miles east of Castle Island, and near to the subjacent limestone, I found impressions of small indistinct bivalves, and of convoluted shells, the latter resembling in form small Goniatites*, together with some impressions of plants. This shale is partly employed as black chalk.

(67.) The anthracitous coal of the Kanturk district, is so ill adapted to culinary purposes, that English or Welsh bituminous coal, is consumed in preference, even so near as in the town of Mallow. The native coal is employed chiefly in burning limestone to provide manure for land, and especially in the reclaiming of waste land, in which application it has rendered most important service to the agricultural interests of the neighbourhood. But as upon these demands, which fluctuate according to circumstances, the supply of the coal necessarily depends, so the quantity annually raised, has varied considerably. During the last war, when a great impulse was given to agriculture, the quantity disposed of from the Dromagh collieries alone, which are the principal, amounted to as much as 25,000 tons per annum. The culm sells at the pit mouth, according to its quality, at an average from ten to fifteen shillings per ton. The collieries of this district are chiefly wrought during the summer months, when labourers can be best spared from agriculture, and the works are least heavily watered.

(68.) A large portion of the South Munster coal tract, is covered with peaty soil; but it may be remarked, that wherever limestone is adjacent, and a facility of intercourse is secured by the construction of good lines of road, the conversion of waste land into productive soil is progressive

* Bearing some affinity perhaps to the *Goniatites sphæricus* or *G. striatus*, discovered by Sir Philip de Malpas Grey Egerton, Bart., and Viscount Cole, in the carboniferous shale of the county of Fermanagh. (Geological Proceedings, No. 32. 12th June, 1833.)

II. Carboniferous Series in North Munster.

In Clare, and extending into Galway.

Old Red Sandstone.

(69.) This formation, in the district under consideration, is quite analogous in composition, structure, and position, to that observed by me in other quarters of Ireland. Its chief mass extends from Derrybryan mountain, on the north, to Lough Derg on the south-east; but from near Lake Youlky on the west, it is continued to the south and east in a narrow belt, encircling the clayslate mountains, and reposing, wherever the contact is observable, in unconformable position; in the higher grounds, in nearly horizontal strata, but on the flanks declining according to the declivity. This may be conveniently observed in the hills lying north of Limerick; and at six miles from the city on the road leading both to Broadford and Killaloe, where the sandstone rests in horizontal strata on the vertical edges of clayslate (the latter ranging east and west), but nearer the vale, the former rock dips toward the south, under angles of 25° and 20°, and the succeeding limestone is in corresponding position, yet in receding, approaches to an horizontal arrangement. These relations are also observable in the strata extending to the west past Croghanambrydy mountain. To the north, Derrybryan mountain, consisting wholly of this formation, exhibits horizontal beds in the higher lands, but inclined on the flanks. Thus, in proceeding west toward Gort, the sandstone strata are inclined 30° and 25° westward, and the succeeding limestone, where first apparent, is in conformable position, but more west it gradually becomes horizontal. In Derrybryan mountain may be found all the common varieties incident to the old red sandstone, including beds of red, indurated clay, and sandstone conglomerate. The latter rock appears occasionally in considerable force, containing, in places, rounded and angular ingredients as large as turkey's eggs; and from its mottled aspect, resembles strongly the sandstone conglomerate north of Waterford bridge, and of the Drumdowney quarries adjoining the Barrow and the Suire*.

Carboniferous Limestone.

(70.) The general tendency of this formation to a nearly perfect, horizontal arrangement, as extending from the county of Galway into and through that of Clare, is remarkable, the deflections from that position being only incidental and seldom important. Undulations on a very large scale occur, yet rarely varying more than a few degrees from the horizon. The chief lines of elevation are adjacent to the old red sandstone. This disposition is well de-

* Geological Transactions, First Series, vol. 5; Memoir on the East of Ireland, §. 149.

veloped, in passing from the western declivity of Derrybryan mountain through Gort (§. 69), across the plains to the limestone hills on the west, which there form the bounding line between Galway and Clare. Near Kilmacduagh Abbey and Rockfield, a few miles west of Gort, are broad sheets of bare limestone rock, extending repeatedly over many acres, and separated from each other, only by small green patches of herbage or pools of water. The eye thus ranges over large fields of naked rock in nearly horizontal strata, but fissured at the surface into quadrangular masses. This desolate scene is continued to the limestone hills on the west, where the same horizontal arrangement prevails, as may be noticed in their escarpments, which being in many places divested of all vegetation, the eye traces with facility the corresponding strata from hill to hill. In the projecting and partially isolated hills, this disposition is very striking, as in those adjacent to Glancolmkill, where terraces of horizontal strata, receding one above another, present the stair-like form, so characteristic of many trap districts.

The Clare limestone is distinguished by the general continuity of its strata. The organic remains which have incidentally appeared to me, correspond generally with those derived from other portions of our field. I have already adverted (§. 57.) to the fossils noticed adjacent to the Shannon by Messrs. Weller, Sheppard, and Wright; and I shall merely add, that in the limestone of the peninsula of Renville, on the south side of the bay of Galway, I met with two species of Pentremites, which appear to be undescribed.

Coal Formation.

(71.) This formation in Clare, as in other parts of Ireland, forms hills of greater or less magnitude, planted upon the carboniferous limestone in conformable position; the latter being at the foot of, or rising only a certain distance up, the escarpment on its northern and eastern sides.

Viewed on the large scale, the entire coal-field may be described as a nearly uniform plane, corresponding to that of the subjacent limestone, the angle of inclination seldom deviating more than a few degrees from the horizon, and the prevailing dip being from the east of north to the west of south. The highest portion of this area is the district of Mount Callan, which rising some hundred feet above the general level of that part of the coal country which is situated further north, is still more elevated above the southern portion of the tract; the surface of the latter gradually declining in that direction nearly to the level of the sea. In the higher grounds, however, as well as in the southern, or lower parts of the field, the coal measures may be occasionally observed, disposed in a gently undulated form.

The general arrangement thus described, may be traced along the eastern

and northern flanks of the coal-field, as well as in the interior; but still more clearly in the mural precipices of the western coast, the natural sections of which, gradually decline in elevation in proceeding from north to south.

(72.) At the northern extremity, at Doolan and the village of Roadford, the limestone is at the foot of the escarpment, and the calcareous base with the superimposed coal measures, may be seen in juxtaposition. The limestone appears also on the beach, and forms the low point of Ballylaline. To the south of the place, where the two formations are seen in conjunction, we look along a range of cliffs facing the Atlantic as far as Luagh Point; and if we afterwards proceed to Ballyelaw Point, still more south, we obtain, in reverse position, a view to the north, extending also to Luagh Point; thus comprising in these two views, the whole of that part of the coast, a range of seven or eight miles in extent. The cliffs are nearly mural throughout, varying generally in elevation perhaps from 200 to 300 feet. In the first and lowest part of the coal measures, displayed in these cliffs, the shales predominate, in which clay ironstone occasionally appears, and also gritstone in thin, subordinate beds; but higher up in the series the gritstones acquire greater magnitude and strength. In no part of this portion of the coast, has any coal been discovered; but excellent flagstones might be raised from the slaty, micaceous gritstone, to any extent and of the largest dimensions.

(73.) On the other hand, if from Ballyelaw Point, or from Liscanon asylum harbour, situated on the east, we cross Malbay to the opposite coast, on the south-east, we find coal in the cliff at Raneen, about five miles from Ennistymond. This is the lowest coal hitherto met with in the whole tract. It is a seam of flaky, tender anthracite, much contaminated with iron pyrites, and averaging about eighteen inches in thickness, the roof being shale, and the floor gritstone flag. It has been wrought to a very trifling extent only, for the purpose of burning limestone, brought from the south islands of Arran; and the furthest drift inland, does not exceed fifty yards in length. The mine is situated about twenty feet above high water-mark, but the seam may be traced on its line of dip along the foot of the cliff to the south, until it sinks below the level of the sea. Above this seam is a second, perhaps 80 or 100 yards higher in the series; it does not, however, appear in the face of the cliffs, which, upon this part of the coast, scarcely attain 200 feet in height. The second seam, which does not exceed eight or nine inches in thickness, consists of solid anthracite, good "sweet" coal, the roof being shale, and the floor fire-clay, having beneath it gritstone flag. This coal was discovered about forty years ago by some Kilkenny colliers; it has been worked to a small extent only.

(74.) Hence along the coast to the southward, no coal has been found, until we reach the vicinity of Seafield, situated about fourteen miles from Ennistymond, and nine miles from Raneen. Culm has been met with on the townland of Cahirush, about one mile north of Seafield, and it is said to be twelve inches thick, but it has not been worked: and culm was formerly raised on the townland of Clahaininch, distant two miles south-west from Seafield. Pits were there sunk through the sand hillocks of the coast to the culm, which however was only six or seven inches thick, and of bad quality. No coal has been discovered further south than this spot. My own observations have not extended along this coast beyond the parallel of Kilrush, but I am assured by different authorities, that the coal measures occupy the whole interval to Loop Head, though coal itself be wanting in that part of the series.

On the south coast of this tract, viz. at Labasheda on the right bank of the Shannon, culm has been also worked on a small scale and only to a slight depth, the pits being soon troubled with water.

(75.) The general view which I have given of the North Munster coal-field, would appear to exhibit no very favourable prospect of its productive power. To the instances of coal having been met with, I have, however, to add the fact that in times of heavy rains, coal has been washed down the ravines on the northern side of Mount Callan (in which direction the coal measures crop out), and in particular on the townland of Sileshawn, part of that of Ballylea, and at a place known by the name of Morrison's Mill.

From the paucity of coal appearing on this line of coast, in which the general flatness of the coal measures is so well displayed, it would seem that the lower part of the series contains very little coal. Hence, the best chance of discovery appears to lie in the more elevated region of the Mount Callan district, in which the coal measures are accumulated in greater mass; and as they there apparently retain their small deviation from the horizontal position, an opportunity might perhaps be afforded, should valuable seams of coal be laid open, of working the whole of that portion of the coal tract *level free*, a circumstance of material importance to the operative miner, as well as to the proprietor of the soil*.

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* This advantage is enjoyed to a considerable extent, in the vast expanse of the coal tracts of the United States of North America. In my route from the Gulf of Mexico up the Mississippi and Ohio rivers to Pittsburgh, and thence overland to Lake Erie and through the State of New York in the year 1834, I was very forcibly struck by the nearly perfect horizontality of the strata throughout; from the first visible rocks of carboniferous limestone and their occasional associates of shale and sandstone, adjacent to the Mississippi and Ohio rivers, to the continuous coal-bearing measures, which come in force near the influx of the Great Kanawha into the latter river, extending thence westward into the state of Ohio, and northward through the Virginia, Pennsylvania, and New York States to lake Erie; the prevailing deviation from that position being a slight inclination to the southward, subject, however, to gentle undulations upon a large scale.

The carboniferous series of the United States, admits of a close comparison with that of the British Isles; and the following view may serve to show their agreement. This view I give as

These views may prove useful, whenever the exploring of this hitherto untrodden region shall be undertaken in a systematic and economical manner; a period, however, which might perhaps appear far distant, if we looked merely to a supply of fuel for local consumption, since the vast tract of peat-bog covering the greater part of the coal-field, and extending from Mount Callan to Loop Head, is provided with a store of that useful combustible which seems almost inexhaustible.

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the general result of the observations which I had an opportunity of making during my travels through those States, compared with the great body of valuable information which has been contributed on this subject by other observers; especially in Professor Silliman's American Journal of Science, the works of Professor Eaton, the distinct publications of our countrymen Messrs. G. W. Featherstonhaugh and R. C. Taylor, and the Transactions of the Geological Society of Pennsylvania[1].

In the State of New York, the carboniferous limestone reposes partly on old red sandstone, partly on transition rocks. At the northern extremity, the old red sandstone which lines the south coast of Lake Ontario, from the west of the Niagara to the east of the Oswego river, distinctly underlies the limestone-shale, and limestone from Queenstown, by the gorge of the river Niagara upward to within two hundred yards of the ferry below the Falls of Niagara, having a gentle dip throughout to the southward. The same relative position is observable west of Lockport, in proceeding east from Lewistown by the line of road leading to Rochester; also in the Genesee river north of the latter town, and in the course of the Oswego river. To the east of the Oswego, the old red sandstone reposes on transition rocks, and, being deflected to the south-east, on approaching the Helderberg mountains, it appears to be overlapped and concealed by the carboniferous limestone, the latter then coming in contact with the transition rocks on the east, which range from Canada to the southward: while still more south, in Pennsylvania, the coal measures appear to overlap the carboniferous limestone on the east, and to come also in direct contact with the transition rocks. In tracing, from north to south, the order of succession, from the carboniferous limestone to the superincumbent coal measures, the same low angle of inclination to the south is observable from Niagara in the direction of Buffalo, and thence along part of the south-east coast of Lake Erie. The same disposition is likewise to be remarked, in passing south by the lakes of Cayuga, Seneca, &c., whose waters find a common outlet on the north by the river Oswego. South of those lakes, the land rises rapidly by an accumulation of coal measures, forming the northern aspect of the Alleghany mountains, and the southerly dip is still observable. These beds form an alternating series, distinguished by the prevalence of red shales and red sandstones with beds of sandstone conglomerate and limestone interposed, but in which coal has hitherto been rarely met with; while in the higher regions this series supports and includes the abundant deposits of coal which occur on the northern confines of Pennsylvania, in the anthracitous coal-field of Carbondale and

[1] See in particular—
In the American Journal of Science: Z. Cist, in vol. iv. J. Pierce, in vols. vi. and xii. Professor Silliman and D. Thomas, in vols. xviii. and xix. A Naturalist in Ohio, in vol. xxv. Dr. Hildreth in vol. xxix. (from 1822 to 1835.)
Professor Eaton, Geological Text-book, 2nd edition (1832), and in the American Journal of Science, vol. xix. (1831), and vol. xxiii. (1833).
Mr. G. W. Featherstonhaugh, Geological Report made to both Houses of Congress, (1835.)
Mr. R. C. Taylor, in Loudon's Magazine of Natural History, (Oct. 1835).
In the first volume of the Transactions of the Geological Society of Pennsylvania (1835): Mr. R. C. Taylor, three papers, pp. 177, 204, 275; Professor Troost, four papers, pp. 224, 232, 244, 248; Dr. Harlan, two papers, pp. 256, 260; Mr. E. Miller, p. 251; and Mr. T. Conrad, p. 267.

Metalliferous Relations of the Carboniferous Series.

(76.) *In the Old Red Sandstone.*—The only spot in which I have met with metal in any material quantity in this rock in Ireland, is in the northern face

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Lackawanna and Wyoming, on the Susquehanna, and the bituminous coal-fields of Bradford, Tioga, Lycoming, and Clearfield.

The main body of carboniferous limestone, which thus underlies the series just noticed, extends from Lake Erie in an easterly direction through the State of New York to the Helderberg mountain, situated about 20 miles S.W. of Albany. Here its course is inflected to the south and south-west, and from the Helderberg mountain it has been traced 120 miles upon that line, extending into Pennsylvania on the right bank of the Delaware river, and flanked throughout on the east by transition rocks[1]. It thus supports the bituminous coal measure series of the Alleghany and Catskill mountains on the north and the east, and incloses and supports on the east also the anthracitous deposits of Carbondale, Lackawanna, and Wyoming, as above stated[2]. The southern border of the carboniferous limestone, intersects in its range, the lakes Seneca and Cayuga, and near the heads of those lakes, on the south, thin layers of bituminous coal have been found in the coal measures; and again further east in Otsego county, in the shale lying above the limestone[3]. In like manner, narrow seams of bituminous coal have been met with in the Catskill range bordering on the river Schoharrie; and again in the southern part of the same range in Ulster county, varying from eight to twenty-two inches in thickness, the beds being here in some places horizontal, but in general slightly inclined to the westward[4]. To what extent other seams of coal may occur in the higher accumulation of these coal measures, subjacent to the great anthracitous and bituminous deposits of Pennsylvania above noticed, remains yet to be proved[5].

In the Alleghany ranges, and thence to the west in particular, in the conterminous regions of

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[1] Prof. Eaton, Geol. Text Book, pp. 66, 67, 2nd edition. [2] Ibid., pp. 90, 121, 124.
[3] Ibid., pp. 79, 110, 121.
[4] American Journal of Science vol. vi. p. 94 to 96.
[5] It may be useful to consider, in this place, the distribution of the *Trilobite* family in the State of New York, in reference to the transition and carboniferous systems respectively.

In the *Transition series* are found,	*Localities.*
Calymene Blumenbachii	At Watertown near Sackett's Harbour; Glenn's Falls; Trenton Falls.
C. selenecephala	New York State.
C. macrophthalma	Ulster County.
C. odontocephala	Ditto.
C. platys	Helderberg mountains near Albany.
Asaphus caudatus	Glenn's Falls.
A. selenurus	Ditto.
A. micrurus	Trenton Falls.
A. Hausmanni	Lake Erie; Helderberg.
A. laticostatus	Ulster county.
Isotelus gigas, I. planus, I. megalops	All at Trenton Falls.
Nuttainia sparsa	Coeymans, near Albany.
Paradoxides Harlani	Trenton Falls.
Cryptolithus tessellatus	Glenn's Falls; Trenton Falls.
C. Bigsbii	Trenton Falls; Champlain Lake.
Triarthrus Beckii	Cahoes Falls on the Mohawk river.

N.B. As on the east of the Helderberg and Catskill mountains, the transition and carboniferous rocks are in contact, e. g. in Ulster county, it may be doubtful to which series one

of Shallee mountain, situated to the north of the Keeper mountain, and south-west of the village of Silver Mines.

Here within the distance of 120 fathoms, are four vertical veins ranging about north and south, and nearly parallel to each other, composed of sulphate of barytes, containing fine-grained galena

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Pennsylvania, Virginia, and Ohio, the continuous coal-bearing measures include, not unfrequently, intercalated beds of limestone, which often contain marine animal remains; and the sandstone and shale accompanying the coal, contain also in some places marine shells and other remains[1]. Some of the coal measures are said also to exhibit in places fossil freshwater shells; and in this series also, beds of sandstone conglomerate are not of uncommon occurrence. The continuous coal-bearing measures extend from the region of the Great Kanawha river to the south-west through Western Virginia, and the eastern parts of Kentucky and Tenessee into the northern parts of Alabama, and to the north-east, as above stated, through Pennsylvania into the State of New York. But the main body of the carboniferous limestone, forms the great basis of the coal series. Yet, even in that main body, valuable beds of coal are found adjacent to the lower parts of the Ohio river in Kentucky, Indiana, and Illinois, and near the conflence of the Missouri with the Mississippi.

In the association of beds of limestone with the coal-bearing measures, we perceive an analogy to similar phænomena, in parts of the coal tracts of the North of England and of Scotland; while in the appearance of beds of coal *low down* in the carboniferous limestone, we find a parallel also in Northumberland, in the North of England[2].

In its western extent into Arkansas, the carboniferous limestone appears to be supported partly by the old red sandstone, and partly by a greywacke tract; while in the higher regions of the territories of Arkansas and Missouri, it supports extended, continuous coal tracts[3].

Speaking generally, the great valley of the Mississippi, of which the mighty stream of that name

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or two of the species, derived from those quarters, really belong, the precise localities not being given.

In the *Carboniferous series*,	*Localities.*
Calymene Blumenbachii	Black Rock on Niagara.
Asaphus limulurus.....	Lockport.
A. Wetherilli	Near Rochester.
A. myrmecoides.....	Genessee county.
A. pleuroptyx	Genessee and Helderberg.
Brongniartia platycephala.....	Lockport.
Dipleura Dekayi	Lockport.
Trimerus delphinocephalus.....	Niagara county.
Paradoxides Boltoni	Lockport.

(See Dr. Harlan in Transactions of the Geological Society of Pennsylvania, vol. i. Prof. Eaton Geol. Text Book, 2nd edit.; and Annals of the Lyceum of the Natural History Society of New York, vol. i.)

I may here add, that the band of transition limestone which crosses the river Hudson, north of the Highlands, and on which Newburg is situated, is associated with clayslate, greywacke and greywacke slate; and the specimens thence derived, in the museum of the Lyceum at New York, exhibit numerous organic remains similar to those which I have noticed in Gloucestershire, Kerry, &c.—April, 1837.

[1] Transactions of the Geological Society of Pennsylvania, vol. i. p. 255.

[2] See on this subject the first volume of the Transactions of the Natural History Society of Northumberland, Durham and Newcastle, which contains many valuable papers in illustration of the relations of the carboniferous series.

[3] See Memoirs of a Captivity among the Indians of North America, by John D. Hunter, 1823,

very sparingly scattered through their substance, or in thin interrupted layers, adjacent to the walls. These veins have been tried by open-casts to a considerable extent, in which they varied

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forms the centre, and toward which converge the Missouri, the Ohio, and the Arkansas, with their various tributaries, may be said to be founded upon the carboniferous limestone; sustaining on the E. and W. high accumulated ranges of continuous coal-bearing measures. Within the valley of the Ohio, however, there occurs a considerable tract in Indiana, Kentucky and Ohio, adjacent to that stream, which is composed of transition rocks, arranged in horizontal stratification, extending from the westward of Louisville to the eastward of Cincinnati, in the direction of Portsmouth, and upholding on the E. and W., the carboniferous limestone and accompanying strata, which appear in those quarters[1].

In the immense expanse of the carboniferous rocks of the United States, stretching on the one hand from the State of New York, on the east, with little interruption, to the territories of Missouri and Arkansas on the west; and on the other again from New York State, on the north-east, to that of Alabama on the south-west, the coal is generally bituminous. But great deposits of anthracitous coal occurring in the north-eastern and eastern parts of Pennsylvania, in the field of Carbondale, Lackawanna and Wyoming, as above stated, and more south in portions of the regions traversed by the Lehigh and Schuylkill rivers, have been referred, by some geologists, to the transition epoch; yet from all that I have been able to learn of their general characters, position, fossil plants and other organic remains, I conceive that they belong to the great carboniferous order. Mr. Z. Cist of Wilkesbarre has shown that there is a continuity in the anthracitous coal formation, extending from a district lying north of Harrisburg, through the regions bordering on the Schuylkill and Lehigh rivers, to the valley of the Wyoming on the Susquehanna, and thence up the valley of Lackawanna, in the direction of Carbondale. Hence to the bituminous coal-fields in Bradford and Tioga counties, situated more west, is a distance of only a few miles, and Professor Eaton conceives these formations to be connected, and to pass into each other as portions of the same geological deposits; a view in which he is supported, not only by the circumstances of position detailed above, but by these anthracitous and bituminous coal-tracts containing fossil plants, identical with those in the bituminous coal-field near Zanesville in Ohio, and with vegetable remains found in the great coal-fields of Europe, at Newcastle-on-Tyne, Saarbrück, &c.; and the

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in which (p. 174,) it is said, "Coal abounds on the Vermilion, Verdigris, Osage, Kansas, Missouri, and Earth rivers, particularly high up on the last, in considerably extended strata."

[1] In the transition tract above referred to, are found, of the *Trilobite* family,

	Localities.
Calymene Blumenbachii	At Cincinnati; Lebanon; Miami River; Louisville.
C. callicephala	Near Cincinnati.
C. microps	Near Ripley.
C. Diops	State of Ohio.
Asaphus caudatus	Near Ripley; Cincinnati; Louisville.
Isotelus gigas	Near Cincinnati.
I. planus I. stegops	Newport in Kentucky; Licking River.

(See Dr. Harlan in Transactions of Geological Society of Pennsylvania, vol. i.)

In the few fossils I collected myself at the falls of the Ohio, below Louisville, and in the hills adjacent to Cincinnati, I was strongly reminded of the transition districts of Gloucestershire, Herefordshire, &c.; but in an increased degree on examining the museums of those two cities, which contained numerous organic remains derived from the tract in question. Among the Polyparia might be noticed in particular, *Catenipora escharoides*, and *C. labyrinthica*.

in width from a few inches to two or three feet; but some of them were found to be discontinuous upon the line of range, terminating in threads. From the excavations made, about ten tons of lead ore were raised.

The sandstone rock in this northern face of Shallee mountain, is disposed in firm whitish or yellowish strata, two and three feet thick, dipping 35° to the north, consisting chiefly of fine grains of quartz closely compacted, and more or less micaceous. In a denuded portion of this rock, about ten fathoms square, I counted at least twenty veins of sulphate of barytes, varying from the size of a thread to two or three inches in width, traversing the sandstone mostly in a direction approaching north and south, but traceable in part to their termination in a filament. These, as well as those bearing lead ore, are evidently all veins of segregation, or of contemporaneous formation with the sandstone, commonly traversing the latter in the line of the dip.

(77.) *In the Carboniferous Limestone.*—The portion of the limestone field contained in the Map, has hitherto yielded no important ground for mining

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opinions expressed, on this subject, by Professor Silliman[1] and Dr. Harlan[2], appear to correspond. In further corroboration of this view, it may be added, that both the anthracitous and bituminous coal regions in Pennsylvania, produce large quantities of clay-ironstone, the usual concomitant of the coal-fields of the great carboniferous order.

This distribution of the coal in Pennsylvania, anthracitous on the east and bituminous on the west, may be compared with the coal deposits in South Wales, where the eastern portions are bituminous and the western anthracitous; and again with those in Ireland, where the northern deposits are bituminous, and the southern anthracitous. But both the Welsh and Irish coal-fields belong to the great carboniferous order; and I anticipate that such also will be admitted to be the case with respect to the Pennsylvanian, which point indeed, in reference to the north-eastern parts of that State, appears to me fully established by Professor Eaton, though obscured by a peculiar diction. The mere quality of coal, as being anthracitous, cannot alone be considered a decisive criterion of its antiquity, though so conceived by some geologists. On the other hand, however, it may be asked, is there any well-authenticated instance of a bed of *bituminous* coal having ever yet been found within the limits of the transition system? I am not aware of such.

I will here only add the general remark, that if the land of the United States be rich in the vegetable productions of warm and temperate climates, it is no less so in the exuberance of its mineral stores, of which the chief are its inexhaustible deposits of coal and iron, the mainsprings of arts and manufactures. In the possession of such treasures, combined with a spirit of activity fostered by free institutions, and the natural and gradually improving facilities of internal and external communication, our American brethren may well aspire to the attainment of a state of greatness and prosperity, not readily brought within the compass of human calculation[3]. (May 1837.)

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[1] American Journal of Science, vol. xix. p. 12.

[2] Transactions of the Geological Society of Pennsylvania, vol. i. p. 258.

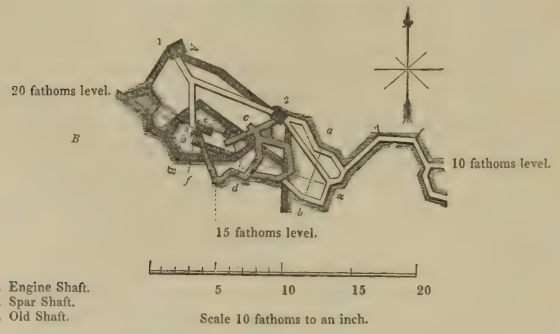
[3] For some other details in exposition of the subject of this note, see also my notices in the Lond. and Edinb. Phil. Mag. for August 1836, and May 1837. And as a corroboration of several of my views in relation to the State of New York, I would refer the reader to *Remarks on the Geology of Western New York*, by Geo. E. Hayes, dated Oct. 1836. See American Journal of Science, vol 31, pp. 241 to 247, which has come to my hands since the preceding pages were written. But to reconcile our language, I should observe that the author employs the term *upper transition* instead of *carboniferous series*. It may also be useful to remark, that with American geologists, *greywacke slate* often implies sandy or quartzy shale of the coal measures; *lias*, argillaceous carboniferous limestone; and *oolite*, an oolitic variety of that formation. (May 1837.)

operations; but those which have been carried on, afford some instructive examples of the modes, in which metal is lodged in the formation.

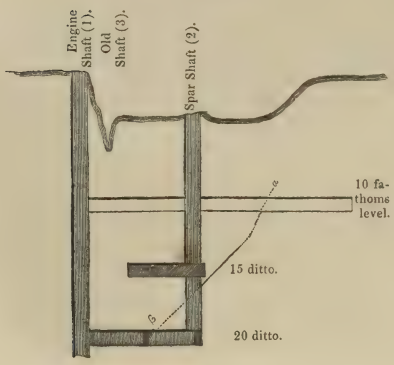
(78.) The Annagh Mine near Castlemaine was discovered about the year 1788, wrought during three years, and then abandoned. Two years afterwards the works were visited by Mr. Raspe, a German miner of reputation, who left a written report dated 4th October, 1793, the substance of which is, "that the mine having yielded 400 tons of argentiferous galena, of the "value of 15*l.* to 17*l.* per ton, from workings which did not exceed twelve fathoms in depth; "and great lumps and masses of ore, lead, and spar, left in the hillocks affording additional evidence "of a valuable deposit, he strongly recommended a resumption of the undertaking, though "doubtful whether the operations had been conducted on a bed or a vein."

The works were accordingly resumed in the year 1825, and the general results may be seen in the subjoined plan and sections.

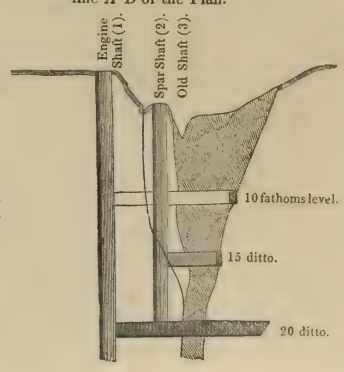
Plan of Annagh Mine, near Castlemaine.



Annagh Mine, longitudinal section.



Annagh Mine, transverse section on the line *A B* of the Plan.



The operations in this mine proved that the 400 tons of lead ore formerly raised, had been derived from a mass of calcareous spar and quartz, firmly adhering to the limestone rock on the northern side, though thinning out in its descent; while on the southern side a great cavity was found, the general slope of which from east to west, is indicated in the plan and longitudinal section by the line $\alpha \ldots \beta$, and its breadth in the transverse section at the respective depths of the 10, 15, and 20 fathom levels, by the transverse lines $a \ldots b$, $c \ldots d$, $e \ldots f$. This cavity was connected on the east and west with collateral fissures, the greater part of which were filled with loose soil and debris. A bed of calcareous spar, situated on the south, was found to vary from 1 to $3\frac{1}{2}$ feet in thickness, and to be, for the most part, barren, yet contained some disseminated galena. This bed and the corresponding limestone strata dip 35° to the north-westward.

The whole quantity of ore obtained by these researches, amounted only to 9 tons 2 cwt. 2 qrs. of lead ore, and a few tons of blende; and the works were in consequence discontinued. The lead ore produced 68 per cent. of lead, and the lead yielded 43 ounces 11 dwts. and 3 grains of silver per ton. The other metallic substances which incidentally appeared, were pyrites of iron, copper, and arsenic, and iron ochre. The whole may be said to have formed a discontinuous, metalliferous pipe, or erect contemporaneous mass.

(79.) From the limestone, about half a mile north of Tralee, which is there disposed in horizontal strata, seventeen tons of lead ore were extracted in the year 1748, and chiefly, as it would appear, from interrupted layers in the rock.

Lead ore was also found in working a limestone quarry north of Ardfert Abbey in the year 1793, but further research was prevented by the lord of the soil. The part of the heap remaining, consists of masses of quartz, containing lumps of galena, calcareous spar, blende, iron ochre, and traces of the blue and green carbonates of copper.

(80.) A few miles north of Rathkeale, in the townland of Ballintreddedy, has latterly been found in the limestone, a vein, three or four, or perhaps more, feet wide, consisting of calcareous spar, antimonial galena, earthy carbonate of lead and oxide of antimony, grey copper ore, antimonial copper ore, blue and green carbonates of copper, and blende. But it has only been touched upon, the proprietor delaying to make adequate researches.

(81.) In the townlands of Curraghanadeely and Ballingarane, a few miles also north of Rathkeale, the limestone strata gently undulate from east to west, and adjacent to the line of parting between them, the rock is in some places metalliferous, containing an intermixture of galena, blende, iron pyrites, and ochre, a few inches in thickness; and to these substances is, in some places, superadded calcareous spar, from six to twelve inches thick: but in neither case does the deposit form a distinct bed. Some calamine also incidentally occurs with the other ingredients. These appearances gave rise to superficial mining operations, which were not attended with advantage.

(82.) To the north of Askeaton, and within a quarter of a mile of the Shannon, in the townland of Ballystein, the limestone contains a bed, dipping 50° to the north, composed of calcareous spar and quartz, bearing lead ore, copper, and iron pyrites, and some blende, and varying from four to sixteen inches in thickness. It was tried upon the range by shallow works eighty fathoms in length, and by two sinkings upon the underlie, of twelve and seventeen fathoms' depth respectively, yet apparently without success*.

* Since the preceding pages were written, some valuable repositories of lead ore have been discovered in the carboniferous limestone in the county of Clare, which are deserving of attention;

(83.) *In the Coal Formation.*—I am not aware of any material metallic deposit having been found either in the North or South Munster coal tracts, beside that of the clay ironstone. But this substance appears so thinly scattered in the coal shales of both districts, that it will probably be scarcely available for the manufacture of iron; for which purpose also the coal is for the greater part wholly unfit, being commonly deteriorated by iron pyrites.

I may mention, however, that a trial for lead was made a few years since on the left bank of the Shannon, south of the river Cashen, on the townland of Mineghane. The cliffs at the place examined, consist of alternating thin beds of brown sandstone and sandy shale, gently undulated both in the line of range and dip, and exhibiting occasionally, though very rarely, a few impressions of indistinct bivalves. In these beds may be sometimes observed a layer of quartz, carious or crystallized, and in a few places small veins of the same substance, both bearing iron ochre, and occasionally small portions of galena; but seldom reaching to a few inches in thickness, and commonly to not more than one or two inches. Analogous trials were made also in Knockpoge West, about half a mile inland from the Shannon. The object of research was in each case unimportant.

(84.) *General Observation on segregated metallic deposits.* The details which I have given of incidental, metalliferous appearances in various parts of the counties of Waterford, Cork, Kerry, Limerick, and Clare[1], are corroborative of a remark which I formerly made[2]; that the diffusion of metallic substances through the mass of rocks (especially of the primary, transition, and carboniferous epochs), is far from being an uncommon occurrence; appearing in isolated particles or portions of greater magnitude, or in layers, veins,

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and for the following information respecting them I am indebted to my friend Mr. John Taylor, who has opened mines upon these deposits. The principal at Ballyhicky, near the village of Quin, a few miles to the eastward of Ennis; a second at Kilbricken, about two miles N.W. from the former; and a third at Milltown, in the parish of Tullagh. Mr. Taylor considers these deposits as erect contemporaneous masses in the limestone rock*, the principal substance composing them being white calcareous spar, in which the lead ore (galena) is distributed very irregularly.

The first work undertaken was that of Kilbricken, in September 1834, and the mass has since been explored eight or nine fathoms in depth, the produce amounting to 25 tons of lead ore, the lead from which, yields 130 ounces of silver in the ton. The ore itself is not so rich in lead as that from the other mines, being considerably mixed with blende; and though it has declined in quantity in descending, an effectual trial of the deposit will be made to a greater depth by means of a steam-engine now erecting.

On the mass at Milltown, it was found, that a considerable excavation had formerly been made, open at the surface. The calcareous spar is speckled with lead ore, but there are no bunches in view which can be called rich. The lead ore obtained from this work by the present adventurers, amounts to about 70 tons, and the lead produces from 50 to 60 ounces of silver in the ton. More extended operations may lead to profitable results.

In the deposit at Ballyhicky the ore was found very near the surface, and rich bunches have extended 9 or 10 fathoms in depth, the deepest part being now 13 fathoms from the surface. The produce hitherto obtained from this adventure, amounts to about 2500 tons of ore, which is remarkably rich in lead, yielding 80 per cent., but the silver contained in this lead is only 15 ounces in the ton. Small quantities of rich yellow copper ore are also found in the mass. This deposit will also be effectually explored to a greater depth, for which purpose a steam-engine is provided. (*March*, 1837.)

[1] See in this Memoir, §§. 18. 34, 36 to 39, 43 to 46, 76, 78, and 81 to 83.

[2] Geol. Trans., First Series, Memoir on the East of Ireland, §. 86. See likewise §§. 18, 28, 38, 99, 105, 109 to 112, 118, 128, 181, and 185, ibid.

* *Stehende Stöcke* of the Germans.

strings, or filaments, more or less connected with each other, yet not persistent, being in fact variously formed segregated deposits, of contemporaneous origin with the rock itself.

III.—Notices of Diluvial Action.

(85.) I cannot conclude these outlines of the mineral constitution of the South of Ireland more appropriately, than by briefly adverting to the distribution of diluvial matter,—a phænomenon which uniformly presses upon the attention of the geologist, whatever be the country or climate in which he may wander. In illustration of the field comprised in the map (Plate II.), a few instances may suffice, taken in different portions, of the southern and northern quarters.

(86.) In Kerry, deep deposits of rolled debris, in the form of boulders, gravel, and sand, more or less commingled with clay, and derived from the general transition series, are lodged around the circuit, penetrate the defiles, and ascend some height up the flanks, of those magnificent mountain groups which distinguish this county, so celebrated for the picturesque scenery which it enfolds within its bosom. On the other hand, on the external borders, marked by the junction of the transition and carboniferous series, the deposits are of a more mingled character, being derived from the superficial destruction of both systems of strata.

Analogous accumulations may be observed also on the confines and in the interior of the carboniferous series. That which occurs on the northern face and at the foot of Slieve Meesh, is an example, composed of the debris of the old red sandstone (§. 49.). Another may be noticed at the western extremity of Kerry Head. The abrupt precipices which there brave the assaults of the Atlantic, are from 80 to 150 feet high, and are generally covered by a mass of sandstone boulders, gravel, sand, and clay ; but on the highest cliff, which also forms the extreme western point, the diluvial deposit consists almost wholly of the detritus of limestone, extending to the depth of thirty feet, and containing but few sandstone pebbles. Now, no fixed limestone rock is found nearer than seven miles, and is there in a lower position, being little elevated above the level of the sea. The surface of the coal tract itself is generally covered, to a greater or less depth, by rolled debris, imbedded in clay, and derived from the harder as well as the softer portions of the coal strata ; but on the borders these are more or less commingled with the detritus of the adjacent limestone.

(87.) In Tipperary, Limerick, and Cork, in the clayslate and greywacke district, which occupies the lower grounds between the Gaultees range on

the south and that of the Slievenamuck, Slieve Riagh, and Seefin on the north, and upholds on each side mountain masses of old red sandstone (§. 48.), are several quarries of roofing-slate, covered by a considerable accumulation, consisting of clay, in which are imbedded numerous boulders and pebbles of slate, greywacke, sandstone, and limestone, and not a few of greenstone porphyry, red felspar porphyry, and purplish claystone porphyry. The first four enumerated kinds of rolled debris, have evidently been derived from the fixed rocks of the immediate neighbourhood. But whence have the porphyries been derived? To find analogous rocks *in situ* we must travel some distance to the north; where they are to be found in association with the carboniferous limestone of Lough Gur, Kilteely, and Pallis.

(88.) The last case I shall notice is in the peninsula of Renville, the western extremity of which, is by land about four miles from Oranmore, and by sea about the same distance from the town of Galway. It forms a low tongue, the base of which is carboniferous limestone, but the surface is mostly occupied by a considerable deposit of limestone gravel and marl, inclosing numerous boulders and pebbles of red and grey granite, syenite, greenstone, and sandstone. This case corresponds perfectly with the preceding. The limestone gravel may be said to be the produce of the immediate subsoil; but the granite, syenite, and greenstone, if not the sandstone also, must have been drifted from the northern side of the bay of Galway, where they constitute an extensive district.

(89.) These instances may suffice to show, that the evidences of diluvial action are no less conspicuous in the South of Ireland than in the other parts of the world, to which observation has extended. And, from the last two cases mentioned above, it might be inferred, that the general current of the waters was from the N.W. to the S.E.; a view which, making allowances for eddies produced by intervening obstacles, is in accordance with my remarks on the East of Ireland[1]: and I may add also with those of Mr. Bryce in the North, as since ably developed, by that author, in his memoir on diluvial action in the North of Ireland[2].

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[1] Geol. Trans, First Series, vol. v. Memoir on the East of Ireland, *Alluvial Tracts*, §§. 202 to 211, and in particular §§, 209 and 210.

[2] Journal of the Geological Society of Dublin, Part I.

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[1] Geol. Trans, First Series, vol. v. Memoir on the East of Ireland, *Alluvial Tracts*, §§. 202 to 211, and in particular §§, 209 and 210.

[2] Journal of the Geological Society of Dublin, Part I.

NORTH EAST OF ANTRIM.

by James Bryce Junr. Esqr. F.G.S.

(p. 69.)

Sheep Isle
Carrick-a-rede
Craigavannon Rock
Kenbane Head
Fairhead or Benmore
Murlogh Bay
Coal Works
Tow Escart
Dyke of Sienite
Primary Limestone
Ballycastle
Drumadoon
Point of Torr
primary limestone
Coolnagopag
Greenstone Slates
Carey R.
Primary limestone
Drumakeel
Ballynagard
primary limest.
Glenmakeeran 1321
Bally Patrick 1160
Carnanmore 1250
Mullach fin
Oour
Granite
Doughan Hill
Knock layd 1685
Glenshesk R.
Carey R.
Cushleak
Ballycastle
Armoy
Beds or lyds par porphyry
Porphyry
primary trap
Cushendun
Cushendun Bay
Brish adhu 1100
Conglomerate
Beiregnachan 1380
primary trap
Cross
Slieve
Glenville
Glendun
Port Vinegar
Cushendall
Court Mc Martin
Cushendall R.
Ballask R.
Rally knock
Slieve an Orra 1676
Glenaan
Kilnadore
CUSHENDALL BAY
Loughguile or Lisanore
Corkey Mountains
Glenariff R.
Red Bay
Teabuliadh 1345
Corlane
Point of Garron
Glenariff
Teavemaile
Trostan 1810
Largeidan Mount.
Slievecance 1782

Mica Slate
Old Red Sandstone
Porphyry
Mountain Limestone
Coal Formation
New Red Conglomerate
New Red Sandstone
Lias
Mulatto or Green Sand
Chalk
Trap

II.—*On the Geological Structure of the North-eastern Part of the County of Antrim.*

By JAMES BRYCE, Jun., M.A., F.G.S.,

(MEMBER OF THE GEOLOGICAL SOCIETY OF DUBLIN, AND OF THE NATURAL HISTORY SOCIETY OF BELFAST.)

[Read May 2, 1832.]

(1.) THE Third Volume of the First Series of the Society's Transactions, contains a Memoir by Dr. Berger on the Geological Features of the North-eastern Counties of Ireland. It is preceded by an Introduction from the pen of Mr. Conybeare, and is followed by a Supplement, the joint production of that gentleman and Dr. Buckland.

The views of the structure of the country given by these authors are, generally speaking, correct; in many of the details, however, there are errors concerning those portions whose structure is anomalous or complex, and are such as strangers might be expected to fall into, who took a rapid survey of the district. Having had opportunities, from my local situation, of examining the North of Ireland leisurely and repeatedly, it was easy for me to become acquainted with the details of its structure; I propose, therefore, to lay before the Society, in the following brief memoir, the result of my observations. As the remarks will be entirely supplementary, it is unnecessary to repeat anything contained in the memoirs referred to.

My attention was first called to the peculiarities of this district by Dr. Mac Donnell of Belfast, to whom, previous writers on the North of Ireland, have been largely indebted, and to whom I am anxious to acknowledge my obligations.

(2.) The district I propose to describe, is the north-east corner of Antrim, between Kenbane Head on the north-west, and Garron Point on the south-east; being about eleven Irish miles long, with an average breadth of ten miles. It is traversed in a north-west direction by the Aura Mountains, a portion of the great chain which runs parallel to the sea-coast through the whole length of the county, and in this part of its course contains several mountains, varying from one thousand to nearly two thousand feet in height. The principal are, Trostan 1810, Sleiveanee 1782, Knocklayd 1685, Sleive an Orra 1676, and

Ben-cruachan about 1500. From the main body of the chain project, in the southern part of the district, several long ridges, with flat, broad summits and precipitous sides. They reach almost to the sea-shore, and are separated by deep and narrow glens, which extend far into the interior; the principal being Glenariff, Glenaan, and Glendun. Through these glens flow rivers of the same name; the waters of which are scanty in summer, but in winter are swelled by many tributaries, from the upland bogs; and tumbling over the cliffs, excavate deep and wide channels, which present to the geologist perfect sections of the strata.

In the northern part of the district, or that which has Glendun for its southern boundary, the surface of the country is occupied, at intervals, by considerable hills, which are detached from the main chain and from one another, but have a northerly direction, parallel to the principal chain. Those which deserve mention are Glenmackeeran, 1321 feet; Ballypatrick and Brishadhu, about 1100; and Carnanmore and Carnlea, 1250 each. They are of an elongated, narrow form, and in general slope gradually; but the eastern sides of those next the sea, shelve down to the shore in abrupt and rugged terraces.

The direction of these hills determines that of the valleys and river courses. The valleys have a north and south direction, and open into a principal one running east and west to the south of the elevated ridge which forms the coast from Fair Head to Ballycastle. The rivers flowing through these valleys turn westward, and pour their united waters into the sea at Ballycastle.

On the western part of the district, the principal chain of mountain descends, in a succession of undulating hills, into the low country, which extends at their base from Corkey by Armoy to Ballycastle.

(3.) The following are the principal formations which occur in the district: mica slate, old red sandstone, porphyry, carboniferous limestone, coal with its accompanying strata, new red sandstone and conglomerate, lias, mulatto, chalk, and trap. Granite, primitive limestone, and porphyry occur as subordinate rocks.

Mica Slate.

(4.) This formation in the north-east of Antrim, does not vary from its ordinary character in the North of Ireland, as described by Dr. Berger. It occasionally passes into gneiss, and by the insulation of the crystals of felspar assumes a porphyritic aspect. It contains crystals of quartz and, rarely, of common schorl, also amorphous quartz, accompanied by chlorite.

Mica slate occupies the greater part of the area under consideration. Its boundary in the south-eastern part of the district is a line ranging, in an irregular north-east direction, from the eastern

point of Teavemuile, a mountain forming the highest part of the ridge which bounds Ballyeemin Glen on the north, across the head of the glen in which Cushendall is situated; and along the north-west declivity of Cross-slieve, to the mouth of Glendun river[1]. From this point it occupies the coast as far as Murlogh Bay. From the base of Tibuliadh near Teavemuile it ranges north-west, conforming in its direction to the eastern escarpments of the Aura Mountains, and constituting their inferior regions; sweeping round the northern front of Bencruachan, which terminates the chain, it turns southwards and composes the lower part of all the mountains as far as Corkey, the whole of the low country which extends from Corkey by Loughguile and Armoy to Ballycastle, and the half of Knocklayd, in which it rises to the height of 800 feet. From Ballycastle its line of junction with the secondary strata trends eastward up the valley of the Carey, and with the stream of which its boundary nearly coincides, then turns northward until it finally dips under a narrow band of secondary rocks to the south-east of Fairhead, and is thus connected with its north-eastern termination in Murlogh Bay. Over all this area the general dip of the strata is south-east at a high angle; but there are frequent irregularities in the dip and inclination, and the strata are often much contorted.

(5.) Other primary rocks occur abundantly, subordinate to the mica slate. Primary limestone is found at Torr Point, and on the declivities of Knocklayd, and in the townland of Ballynagard, near Ballycastle. Beds of felspar, porphyry, hornblende rock, and hornblende slate occur in several places. These have all been described by Dr. Berger. Granite is found near the village of Ardsillach on the road from Cushendun to Torr. It occurs in the face of a hill called Deaghan, which overhangs the road; the bed is conformable to the mica slate; it is several yards wide, and is probably connected with a subjacent body of the same rock. It is composed of red felspar, which is the predominating ingredient, of minute portions of vitreous quartz, and of small crystals of brown mica.

Old Red Sandstone.

This rock has little of the conglomerate structure; being most commonly a coarse-grained whitish sandstone, with a little admixture of argillaceous and calcareous matter. It contains some fragments of other rocks, but in very small proportion to the mass.

The fragments are water-worn masses of resinous quartz, varying in magnitude from the smallest particle to the size of a man's head; also several varieties of porphyry, many of them the same as those of Kilnadore and the Knockans, afterwards to be described; but many of them have no resemblance to those porphyries, subordinate to the mica slate, or to any other porphyry known by me *in situ* in the North of Ireland.

Some of the imbedded masses are the same as the base itself, showing either that parts of the rock have been derived from preexisting portions being worn

[1] See after Article 7.

down and afterwards recomposed; or that a preexisting rock of very similar structure has been entirely worn away in supplying materials for this great mechanical deposit. I have observed no pebbles of granite or mica slate. The largest of the fragments are identical with the base itself, while those of quartz are by far the most numerous. In most of the strata the fragments are few: they are rare in those adjoining the mica slate, while they occur in greater quantity and variety in those in contact with the newer conglomerate. Many of the strata, however, include no fragments, and in others they are collected into distinct groups in different parts of the same stratum, the remaining portion being quite free from them. The rock, moreover, often loses its coarse-grained gritty structure, and assumes a fine-grained sandy texture, like a grey freestone; but by far the greater part possesses the appearance and structure formerly described. A sandstone occurs under low-water mark, in advance of the cliffs near the collieries at Bonnycastle. It is overlaid by the carboniferous limestone, and must therefore be the old red sandstone.

(7.) This rock extends from Cushendun to the head of Ballyeemin glen, occupying the greater part of Cross-slieve, the upper portion of the glen in which Cushendall is situated, the lower part of the southern side and the greater portion of the bottom of Ballyeemin glen, also the whole southern declivity and half the table-land of the summit of the ridge which forms the northern side of that glen; the rest of the summit and the whole northern front being composed of mica slate, which seems to constitute the greater part of the ridge, as the covering of sandstone is very thin along the southern side. In the eastern face of this ridge, in the town-land of Tavnagharry, the mica slate protrudes from beneath the sandstone and occupies a small gulf-shaped area, surrounded by the sandstone on all sides except the north, where it is joined by a narrow neck, or isthmus, to the great body of the same rock. The Ballyeemin river crosses the southern part of this area; and the mica slate is seen in the bed of the river, overlaid, on the left bank, by the sandstone. In the bed and banks of the same river, near the head of the glen, two isolated patches of mica slate are met with, separated from one another by beds of sandstone of small extent, and are probably portions of the rock elevated above the general level, and from which the sandstone, having nearly thinned out in this part, has been worn away. The intervening beds of sandstone seem to occupy a trough or basin between these two projecting peaks or spires of mica slate. The newer conglomerate, which will be immediately described, and which here contains enormous masses of mica slate, reposes immediately on the mica slate forming the upper of these two isolated portions, the old red sandstone being most probably overlapped, or having thinned out.

(8.) Over all the area occupied by the old red sandstone, the strata dip uniformly to the east. The angle of inclination, however, varies, being generally about 40°, and rarely less than 25°. Near the mica slate it is high and conformable to that rock, while at points remote from the schist it is less.

Porphyry.

There are several varieties of this rock. The most common is a clay porphyry, of red, grey, brown, reddish grey, and bluish red colours, irregularly intermixed in every possible manner. It contains crystals of glassy felspar, vitreous quartz, and calcareous spar, and small crystals of brown mica[1]. The crystals often disappear, and the rock passes into a claystone, or into an argillaceous sandstone, closely resembling the base of the finer varieties of the old red sandstone.

Another variety is a clinkstone porphyry, of a bluish or greenish colour, which seems to pass, in some instances, into a close-grained greenstone.

The area occupied by the porphyry is an irregular triangle, extending from Cushendall on the north to a little beyond the Knockans on the south-west: its eastern boundary being the sea between the mouths of the Cushendall and Balleask rivers. Within these limits the porphyry is continuous, and does not crop out in *independent* masses, as stated by Dr. Berger[2].

The strata of old red sandstone which are interposed on its western boundary between the mica slate and the porphyry, preserving their usually high inclination, dip uniformly eastwards, so as to pass under the porphyry. The summit of Court McMartin, a hill immediately adjoining Cushendall, is composed of porphyry, but the old red sandstone appears in its lower part. The isolated hill Teavaragh, behind Cushendall church, has also a base of old red sandstone. Strata of clinkstone porphyry crop out in its middle, while its summit is composed of a disintegrating green-stone. Further, the newer conglomerate on the shore covers the porphyry. It would appear from these facts, that the porphyry overlies the old red sandstone, through which it has been most probably erupted, and that it is covered by the new conglomerate.

Few[3] junctions being visible, there is little opportunity of observing alterations such as igneous rocks usually produce upon the sedimentary deposits; two instances, however, occur. At the mouth of the Cushendall river the strata of the newer conglomerate are tilted by the porphyry from their usually low inclination to a nearly vertical position; but, as the contact of the two rocks is concealed, it cannot be determined whether any change of structure is induced upon the conglomerate. At the base of Teavaragh the old red sandstone is considerably indurated by the contact of the clinkstone porphyry which overlies it.

[1] Masses of jasper also occur.

[2] See Dr. Berger's Paper, Geol. Trans., 1st Series, vol. iii. p. 201.

[3] The following paragraph was added by the author, in April, 1836.

(10.) Mr. Conybeare noticed a bed of clay porphyry on the west side of Fairhead, under the level of the coal formation; it is probably contained in the old red sandstone mentioned as occurring there. If so, the analogy between its position and that of the Cushendall porphyry is striking and illustrative. The rock in both localities would thus be contained in the old red sandstone, and the new conglomerate which covers the porphyry at Cushendall overlies the coal formation in Murlogh Bay. (See after, art. 16.)

Other points, near Cushendun, at which porphyry occurs, are noticed in the map.

Carboniferous Limestone.

(11.) This rock is fully described by Dr. Berger. It appears on the shore near the Collieries, under the coal-field; but is of very small extent, and does not occur in any other part of the district.

Coal Formation.

(12.) The coal measures exhibit the usual alternations of coal, sandstone, slate clay, and bituminous shale. To the accounts of it by various authors, I shall add only a few observations on its superficial extent.

It has been stated, (p. 72) that the formation reposes at its northern extremity upon the carboniferous limestone, underlaid by old red sandstone; on its southern boundary it rests immediately on mica slate[1].

The sea is the northern boundary of the coal-field from Ballycastle on the west to the south-east corner of Murlogh Bay on the east; its southern boundary almost coincides with the Carey river from Ballycastle to the townland of Drumnakeel, where that river turns westward into the valley before mentioned. Here its boundary turns north-east and passing through Drumadoon, ranges by the trap of Fairhead; and then extends eastward in a narrow zone between the trap and the mica slate, and, passing afterwards under the chalk, finally expands into a deposit of considerable importance in Murlogh Bay.

The coal strata thus emerge on all sides from beneath the basaltic mass of Fair Head, which is by this means isolated. The usual alternations of sand-stone with slate clay and bituminous shale appear in many places; but are exhibited beautifully in a section on the banks of the Carey river.

(13.) In Murlogh Bay the beds are precisely similar to those in other parts of the field. A sandstone cementing small quartz pebbles occupies the shore, and is well seen near the great dyke. Mr. Conybeare thinks it identical with

[1] See particularly the very valuable "Geological and Mining Survey of the Antrim Coal District," by Richard Griffiths, Esq.; in which an accurate account is given of the various beds of this formation.

the Cushendall conglomerate. It is undoubtedly much older, as I shall presently show. The same rock, though less gritty in structure, extends to a considerable elevation in the bay, and alternates with beds of slate clay, and a dark blue, bituminous shale, as in the cliffs west of Fairhead. There also adits were made into the sandstone, and a considerable quantity of coal was obtained, but the workings are now abandoned.

Fairhead reposes upon the coal formation. At the south-western termination of the area, near Maghera and Cairnlogher, in the county of Derry, a small coal formation occurs, resting upon carboniferous limestone and old red sandstone on the one side, and upon mica slate on the other, thus affording a complete analogy with the Ballycastle district.

New Red Sandstone and Conglomerate.

(14.) The conglomerate of this formation has been fully described by Dr. Berger and Mr. Conybeare. In addition to the fragments observed by them, I noticed a few small round pieces of red granite, which would seem to have been derived from the beds of that rock, subordinate to the mica slate. This conglomerate passes (apparently) into old red sandstone on the one hand, and into red marl on the other. It lines the coast from Cushendun Bay to the commencement of the porphyry, at the mouth of Cushendall river, and extends a short distance from the shore into Cross-slieve.

At Cushendall caves, the red sandstone alternates with the conglomerate; but is so free from fragments, that it is quarried in considerable quantity and shipped for Belfast. The cement of the conglomerate also often passes from its ordinary coarse, reddish, and highly quartzose state into a finer and white sandstone, indicating a passage from the one rock into the other. Indeed so close is the connexion in mineral structure, that it seems almost impossible to draw a precise line between them.

On the shore near Port Vinegar, the masses of porphyry imbedded in the conglomerate, are more numerous than at any other place, and are all identical with the adjoining rock; and as almost every variety is found in rolled and angular pieces, a great part of the conglomerate at this point, has been produced, apparently by the wearing down of the porphyry.

At the southern termination of the porphyry the conglomerate is resumed, and extends to the mouth of Glenariff river. A change there takes place in the base of the conglomerate,—it first passes into a coarse red sand, containing the usual fragments; then into a fine stratified red sand, in which the fragments are loosely imbedded, adhering neither to the base nor to one another. These fragments gradually diminish in size and in quantity, until they ulti-

mately disappear and the rock becomes a fine marl. Thus the conglomerate, with its enormous, imbedded masses, graduates so imperceptibly into a fine red sandstone, that it is altogether impossible to separate them in nature.

The strata of the conglomerate on the shore, have an inclination conformable to the old red sandstone on which they repose; but near Red Bay castle, where the conglomerate graduates into red marl, its strata gradually pass from their usually inclined to a horizontal position, which the red marl afterwards preserves.

The strata of the conglomerate are also horizontal along the front and north side of Lurgeidan mountain; and they are never found inclined in the interior.

The conglomerate does not extend further south than the opening of Glenariff-glen. It rises to a considerable height on the eastern front of Lurgeidan Mountain, and stretches in a narrow zone around its northern base to the head of Ballyeemin-glen; but the whole stratum soon after thins entirely out in the eastern face of Teavemuile, in the upper part of Corlane. Its prevailing character in the first part of its course is that of a siliceo-argillaceous base of a reddish grey colour, including numerous round and angular fragments of various sizes of quartz and mica slate, with smaller of red granite. Here also it rests in nearly horizontal strata upon the edges of the highly inclined beds of mica slate and old red sandstone, and when near the mica slate its base is often very micaceous.

(15.) The red marl occupies the bottom and sides of Glenariff to a considerable height; and its uppermost strata, next the mulatto or green sand, are highly argillaceous, but never contain gypsum. That substance does not appear until after turning the point of Garron, where it is found in the argillaceous marl, subordinate to the sandstone. White and blue clay-galls also, are not unfrequent in the red sandstone of Glenariff. From Glenariff the red marl ranges round the front of Lurgeidan Mountain, overlying the conglomerate, but in a narrower zone, and turning westward along its northern side, runs out in the townland of Cuilags, a considerable distance east of the termination of the conglomerate. The same gradation between these two deposits, which I have described in Red Bay, is everywhere observable. In Mullach-fin-ooar, between Ardsillach and Torr, a patch of red conglomerate is interposed between the mica slate and the chalk; it includes loosely imbedded fragments of mica slate and quartz, and is very like the conglomerate of the caves in Red Bay. It extends along the south-east face of the hill fronting the sea.

(16.) The red sandstone and its conglomerate are fully developed in Mur-

logh Bay, and present the same structure and the same gradations which have been already described (14, 15). The conglomerate covers the coal sandstone, and is identical with the less coarse varieties of the Cushendall conglomerate, particularly those of the cliffs in Red Bay, the fragments being as usual quartz and mica slate of various sizes, imbedded in a coarse sandstone of a reddish colour. Both the conglomerate and red sandstone terminate abruptly against the mica slate in the southern corner of the bay. On the northern side, the conglomerate extends under the greenstone of Fairhead, the red sand having previously thinned out. To what distance it ranges in this direction it is impossible to determine, the strata are so completely hidden by subsidences; but it is possible that it soon terminates, since it appears from sections exposed in other places, that the Fairhead greenstone reposes upon the coal sandstone itself.

(17.) It has been thought that the trap and sandstone alternate here. I could detect no such alternation; and the mistake arose from "viewing the conglomerate in relation to some subsided masses of greenstone," as has been well remarked by Mr. Conybeare.

(18.) It may be questioned whether the rock which I have called new conglomerate, should be separated from the old red sandstone. The facts surely warrant such a separation; and it may be well to recapitulate them. In our old red sandstone granite or mica slate pebbles never occur, while both are found, the latter most abundantly, in the conglomerate. The conglomerate covers the mica slate and old red sandstone unconformably. The porphyry overlies the old red sandstone, but is covered by the conglomerate: besides, in Red Bay and Murlogh Bay, there is a clear gradation from the conglomerate into the new red sandstone.

(19.) This whole series of mechanical deposits with the intrusive rocks, is analogous, in many respects, to the conglomerate and accompanying rocks which occur in South Devon, the theory of whose origin is so well given by Mr. De la Beche in his Geological Manual (pp. 400, 405. 2nd edit.).*

Lias.

(20.) Upon turning the Point of Garron and advancing towards the opening

* In Dr. Berger's Map, the greater part of our district is coloured as composed of new red sandstone, whereas that formation is of very trifling extent, the mica slate occupying by far the greater portion of the area. In the notes to the coast sections, similar mistakes continually occur. Tea-bulioah and several other mountains are said to "exhibit basalt, chalk, and *red sand*," while not a particle of red sand is to be met with beyond the limits described. This will appear sufficiently from the details already given. (1836.)

of Glenariff-glen, the lias which extends almost without interruption from Larne, again appears from beneath masses of fallen rocks, which strew the whole space between the shore and the cliffs: the only stratum visible is the slate clay; no limestone having been detected. The thickness of the deposit is here greater than on any other part of the coast, except at the little deer park of Glenarm; but it cannot be accurately determined. The slate clay is well seen on the road-side, a little west of Cloch-a-stukan; and the soft substratum having given way, the road has sunk considerably. It terminates before entering Glenariff, the mulatto from this point resting on the sandstone, until near Ballintoy at the extreme north-western corner of the district, where the lias reappears.

Mulatto or Green Sand.

(21.) Dr. Berger noticed, that the upper beds of this rock are of a homogeneous sandstone, while the lower frequently include quartz pebbles, and thus assume the conglomerate structure. These two varieties are constant in their character and relative position, from the Point of Garron to the eastern flank of Lurgeidan Mountain; where the sandstone thins out, and the mulatto for the remainder of its range is a conglomerate. Under this form it continues its course between the chalk and the newer red conglomerate as far as the eastern part of Teabuliadh, where it ultimately disappears, extending some distance beyond the termination of the red conglomerate, and thus reposing on the mica slate. From the point where the mulatto sandstone ends, the mulatto conglomerate begins to contain fragments of mica slate in addition to the quartz pebbles, which alone had entered into its composition before; and they become much more numerous from the point where it begins to repose upon the new red conglomerate. It never contains the red granite found in the conglomerate; but fragments of a white carbonate of lime, like an indurated chalk, are not unfrequent. It is difficult to say whence this limestone was derived.

The existence of beds of mulatto near Armoy, on the western edge of the district, seems indicated by loose masses strewing the surface; but as no section is exposed, the mulatto, on this part of the map, is marked as doubtful.

Where the stratum is fully developed, in the first part of its course, its thickness varies from six to ten feet, the conglomerate bed forming about one third of the whole. In the latter part of its range, where the brecciated bed alone occurs, the thickness varies from nine inches to three feet.

In Farous-glen, on the south side of Glenariff, in the bed of a river which exposes a vertical section, the red sandstone is succeeded by a bed of blue argillaceous marl two or three feet thick, similar to that, which, in most places, forms the upper member of the sandstone series. On this marl the mulatto conglomerate rests, and is interstratified with a few thin seams of the argillaceous marl. That part of the marl which is interstratified with the mulatto, and the overlying portion to the thickness of six inches, contain very few pebbles; while the superior portion includes them in great numbers. In the north-east face of Lurgeidan Mountain, veins of mulatto, not exceeding two inches in thickness, pass irregularly to the depth of from five to fourteen inches through the upper beds of the new red sandstone, which are here a fine red sand. The sandstone between the seams is charged with calcareous grains; and the regular stratum of mulatto conglomerate, which is here about one foot thick, is arenaceous in its lower part. This may be regarded as a rudimentary formation of the lower greensand, which attains a full development in other places, beyond the limits of our district. Both these instances of interstratification, are unexampled among the upper secondary deposits of the North of Ireland.

A brecciated mulatto inclosing quartz pebbles only, and about three feet thick, underlies the chalk in Murlogh Bay, terminating against the mica slate in the south-western corner of the bay.

Chalk.

(22.) The chalk having ranged round the sides and across the lands of all the glens from the Point of Garron to Teabuliadh, continues its course in a north-west direction, along the eastern declivity of the principal chain, then turning round the northern front of Bencruachan, takes a southerly direction along the western escarpment as far as Corkey. Here, after a short sweep to the west, it turns again northward, and continues in that direction by Ballyknock, Armoy, and Balleeny, to Ballycastle, where turning again westward, it forms the coast by Kenbane and Ballintoy towards the Causeway. In the interior of the country, the chalk constitutes part of the four isolated hills, Knocklayd, Ballypatrick, Carnanmore, and Mullach-finooar, all ranging in a north and south direction, and lying in the same parallel of latitude. In the three former it is covered by a thick cap of trap; but in the latter it is uncovered.

It is also uncovered by trap in the northern part of Carnanmore, and extends thence in a zone of considerable breadth through Coolnagoppoge and Ballynean, to the cliffs above Murlogh, where it abuts abruptly against the greenstone of the Fairhead.

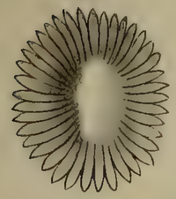
This zone presents the greatest surface of chalk uncovered by trap in the North of Ireland; and it is here only that the peculiar vegetation of the chalk is exhibited. The soil is a light dry mould, covered by an intensely green turf, which is bespangled with myriads of daisies.

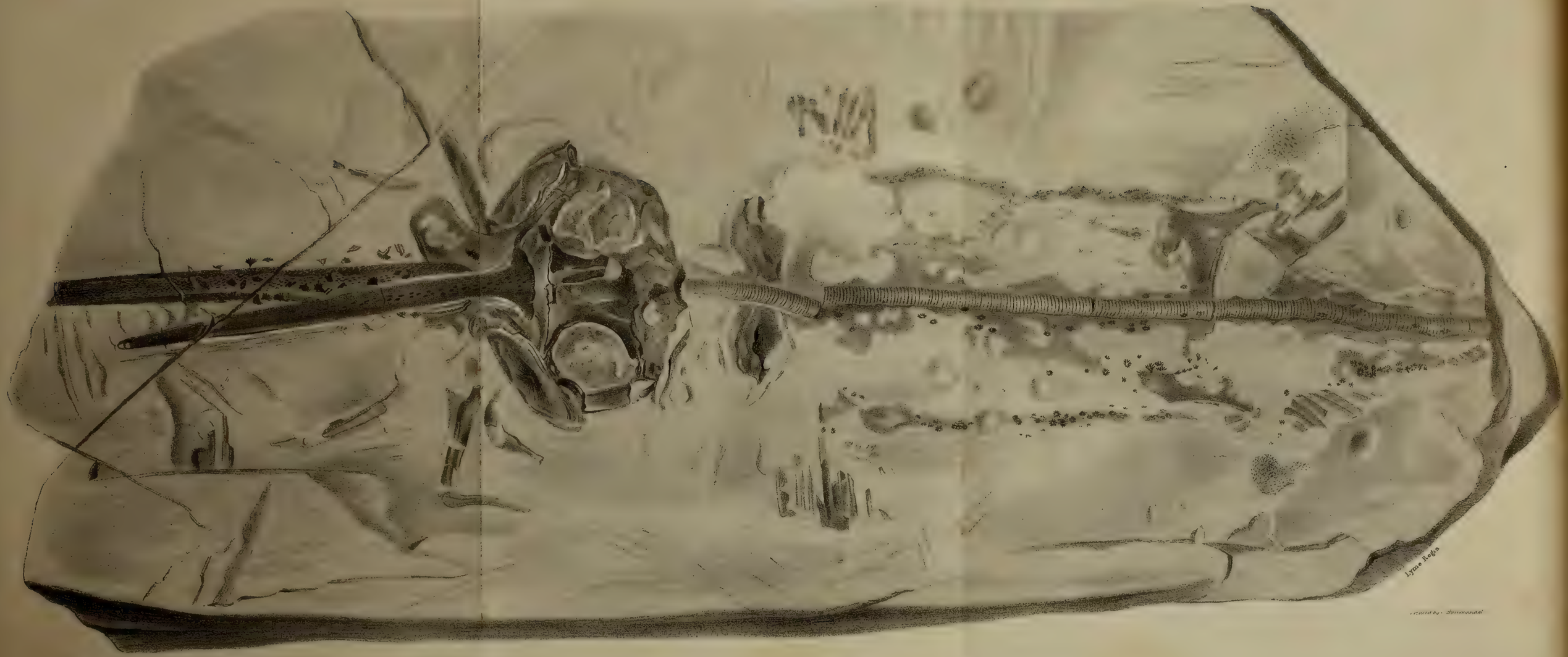
(23.) We have seen, that the upper beds of new red sandstone in Glenariff pass into an argillaceous marl, which, however, does not contain any veins of

Fig. 1

Fig. 2

Fig. 3





SQUALORAIA.

(p. 83.)

III.—*On the Squaloraia.*

By H. RILEY, M.D.

Communicated by Charles Stokes, Esq., F.G.S.

[Read May 15, 1833.]

THIS interesting animal, of which Plate IV. is an accurate representation*, was discovered in the lias of Lyme Regis in 1831 by Miss Anning, associated with the Saurian and other remains, for which that place has become so celebrated.

It was purchased by John Naish Sanders, Esq., and deposited by him at the Bristol Institution, where it now constitutes a part of that valuable and improving collection.

The form of this animal is so striking and peculiar, that the majority of observers have disagreed not only as to its genus, but even as to its class: for by the generality it has been pronounced a Saurian, and by a few even a bird.

Those who advocate the former of these opinions, are led to do so from the form of its parietal bone and its elongated jaws. The latter character was likewise the reason for supposing it to be a bird.

But the absence of alveoli and teeth, and of respiratory openings; the form and number of the vertebræ; the form of the thoracic and pelvic regions, with their attached members, render the former opinion but little probable.

The other supposition is so at variance with all the anatomical details of the fossil, that we shall not trouble our readers with its discussion. For our own part, we cannot avoid concluding that it is a cartilaginous fish, having many points of resemblance to some of the Rays, but differing from them in several important characters.

The entire length from the end of the lower jaw to the fractured extremity of the tail is $17\frac{1}{2}$ inches. The greatest length of the head, $7\frac{1}{2}$ inches. Breadth across the orbits, $3\frac{1}{2}$ inches. Length of the remains of the vertebral column, 10 inches†. Extreme width, $5\frac{1}{2}$ inches.

* Copied by permission of M. Agassiz from Plate XLII., vol. 3. of *Les Recherches sur les Poissons fossiles.*

† Nearly the whole of the remainder of the tail has been subsequently found, and measures rather more than ten inches, including about 240 vertebræ; and is in the possession of Miss Philpott.

The animal is imbedded in the lias with its belly downwards; whilst, therefore, we have an excellent view of the whole of its superior surface, we have no means of observing its inferior or abdominal. It has, however, on the most superficial inspection, a strong resemblance to the flat cartilaginous fishes; and this is not confined to the form alone, for there are distributed all over its surface an immense number of spines with radiated bases, (Plate IV. Fig. 1—3.) the remains of its dermoid apparatus. They are best seen around the head, and on each side of the terminal pieces of the head. These spines are identical with those of the Rays.

In studying the head (Plate IV.) we can distinctly observe at its posterior face or boundary, two processes projecting backwards, flattened laterally, and bounding the occipital hole; being evidently the remains of occipital condyles. Allowing for the process of flattening, the forms of this region are not unlike those of the Rays.

Superiorly, and on the median line corresponding to the occiput, the bone or cartilage has been greatly defaced; but the parts between the orbits are in excellent preservation. They are much depressed on the median line, but rise in elevation as their lateral portions form the internal boundaries of the orbits.

This space in form and position, and indeed in all its characters, has a very close resemblance to the same region in the Rays. In them the cartilage corresponding to this space, becomes a mere membrane, and is termed the "fontanelle."

The depression and flattening in our specimen might have depended on the same modification*.

In front of the "fontanelle" are two terminal prolongations. The superior has been fractured at its posterior extremity, and thrust backwards as far as the anterior edge of the orbits. It has likewise been broken in two other places near the middle. It is elongated, conical, flattened posteriorly and superiorly, but becomes more rounded towards its anterior extremity. Firmly attached to its superior surface, are many of the small spines already noticed. In its displacement it has been moved obliquely backwards, so that we are unable to observe the superior surface of the inferior prolongation.

This prolongation is likewise elongated and conical; its length was probably greater than the preceding, for its anterior extremity is broken and

* This appearance of the interorbital region, has led the majority of observers to consider the animal in question a Saurian: we trust, however, the arguments we have advanced are sufficient to show the contrary to be the case.

has been lost. The superior surface instead of being convex like the former has a very wide and superficial groove, the boundaries of which are the edges on each side, elevated into a corresponding ridge.

These ridges are higher and wider posteriorly than anteriorly.

The form of these terminal cartilages in the Rhinobatis is, in their essentials, like that of our specimen.

In studying the lateral regions of the head, and proceeding from behind forwards, we find the parts posterior to the orbits much injured; portions, however, of bone or cartilage may be seen on the posterior edge of the left orbit, extending downwards and forwards, so as to constitute its lateral and external boundary. From the position, form, and direction of these fragments, supposing the fish to be a cartilaginous one, we think they are probably the remains of the *os quadratum*. The orbits themselves are of large size, and well defined, particularly the left. In front of the orbits is, on each side, a large elliptical mass. In form and position it resembles those swellings of the cartilage which in the Plagiostomes, and the Skates in particular, constitute the seat of the organs of olfaction. These olfactive cavities are much compressed vertically*.

These spaces have on both sides a number of pieces or parts more or less connected with them; but having evidently undergone great mutilation, their determination becomes a matter of some difficulty. We cannot trace any connexion between them and the anterior extremities of the thoracic members, which in many cartilaginous fishes are prolonged as far as this point. Are they feelers? or, are they bones or cartilages extending from the upper to the lower jaw?

* Since the above memoir was written, this country has been honoured by the presence of Dr. Agassiz of Neuchâtel, and gladly did we avail ourselves of the opportunity, during a transient visit he made to the city of Bristol, of laying before him our very interesting fossil: we now with much pleasure acknowledge that to his keen observation and perfect acquaintance with the science of Ichthyology, we are indebted for some determinations which had escaped us. On removing with his penknife some fragments of shale, he discovered several minute teeth along the line separating the elliptical masses or olfactive cavities from each orbit: therefore these portions must be considered as the olfactive cavities pressed closely against the maxillary bones; and in the line of their contact, and consequently along the anterior edge of the orbit, would be situated the teeth attached to the superior maxillary bone having its usual position. A reference to these parts in the common Skate will render this very evident.

The overlooking this circumstance in our determination of these parts, and the rectifying of our error by Dr. Agassiz, lead us to withdraw the specific name of Dolicognathus as being no longer applicable: we hope ere long to have the pleasure of seeing Professor Agassiz's views regarding this very curious fish, registered in his *Poissons Fossiles*.

The anterior piece on the right side, is evidently continuous with the cranium; the middle one on the left presents the appearance of a joint: but we do not recollect to have seen jointed feelers. In the common Skate are two small bones in this position, and in the *Squalus Squatina,* the only specimen of a Squale in our possession, are three large bones or pieces extending from the upper to the lower jaw, and placed considerably anterior to the temporo-maxillary articulation. Two of these pieces are articulated with the upper jaw at one end, and by the other with the third piece, which extends itself to the lower jaw.

Although these analogies are very imperfect, we cannot help thinking that if more extensive means of comparison were in our possession, we should find that they belonged to the latter category.

Behind the cranium in the cervical region, are several detached elongated pieces, which we are inclined to consider as remains of the branchial apparatus; on the left behind the orbit, is a portion lying at right angles with the vertebral column, another is parallel, a third is to be seen to the right.

What remains of the vertebral column, is less injured than the other parts. The processes of the vertebræ have disappeared, leaving the bodies which are circular very perfect. They are concave anteriorly as well as posteriorly, as may be seen at the places where they have been fractured.

This column, or the cycleal elements of it are cylindrical, its transverse diameter seems rather to increase towards the posterior extremity.

The vertebræ are extremely numerous, and are injured in a few places, which prevents our counting them very accurately. There are about 260 in the whole, of which 28 are cervical, counting as far back as the middle of the transverse piece, corresponding to the scapular region; 143 dorsal, counting to the middle of the pelvis; and the remainder, 90, belong to what remains of the tail.

Their transverse diameter is six times more than their antero-posterior diameter.

In the Rays the cervical portion is consolidated inferiorly into one entire piece,—in the Squales it consists of distinct vertebræ; indeed the analogies of form in this column with that of the Squales, are much closer than with any other genus with which we are acquainted; for in the Squales, as in the common Shark for instance, the cycleal elements of the vertebræ or the bodies are quite round. In them the vertebral canal can hardly be said to be formed at the expense of the bodies, which present a very superficial groove only, at their superior surfaces for the reception of the spinal marrow, the canal being principally made up by the epial elements, in other words, by the plates and spinous processes, which in many of this genus are very easily detached.

This canal is more deeply grooved in the bodies of the vertebræ of the Rays, whilst the plate and spinous processes are in general wider and stronger, and more firmly attached.

On casting the eye along the upper surface of the column of the fossil, it is easy to recognise traces of the spinal canal in the form of a very superficial groove; which is more evident in the posterior than in the anterior half.

From the above details we should be inclined to consider this animal as having a column resembling that of the Squales.

The thoracic and pelvic members are next to be considered.

They are greatly injured, hardly an entire piece remaining, and it is evident that with the view of rendering the form of these parts more clear and decided, great liberties have been taken with the specimen.

The scapulæ have disappeared, but we can make out the remains of pieces corresponding to a sternum and pelvis.

We can likewise recognise the radiated form of the thoracic and pelvic members, and can easily trace the anterior member backwards as far as the pelvis, circumscribing an oval space, with the vertebral column running through its centre.

This space would correspond to the seat of the alimentary canal and organs of generation.

It is dotted with an immense number of small spines, of the same form with those so often alluded to, but seems to have suffered from the measures resorted to for an advantageous display of the vertebral column.

Those parts, which in the fossil put on the appearance of radii, belonging to the thoracic member, are distinct from each other, but do not present any traces of joints, a character in which they differ greatly from the Rays, whose radii are jointed. The spaces between these radii have been apparently cut into grooves by a knife, which has injured them.

The forms and arrangement of the pelvic radii are by no means dissimilar from those of the Rays. There are no signs of the powerful claspers to be found in the males of this family.

We are not able, for want of a greater number of skeletons, to determine the original form of the transverse piece in the region of the scapulæ. The portion which must have passed over the vertebræ, corresponding to the scapulæ, has been destroyed, whilst the part which is to be seen lying under them remains, but has been greatly mutilated.

This portion in the Rays would correspond to that transverse cartilage, which connects the thoracic members with each other under the bodies of the vertebræ. By its position and flattened form, increasing in width at each extremity, it resembles the piece occupying the same position in the Rays, and would correspond to the sternum.

But the form of this region in the fossil differs from that of the same region

in the Rays, since in the latter the vertebræ are consolidated into a single piece, and are continuous with, and firmly united to, the two pieces of cartilage or scapulæ meeting on the median line above them.

The right side of the pelvis is less injured than the left, and resembles that of several of the more common species of the Rays.

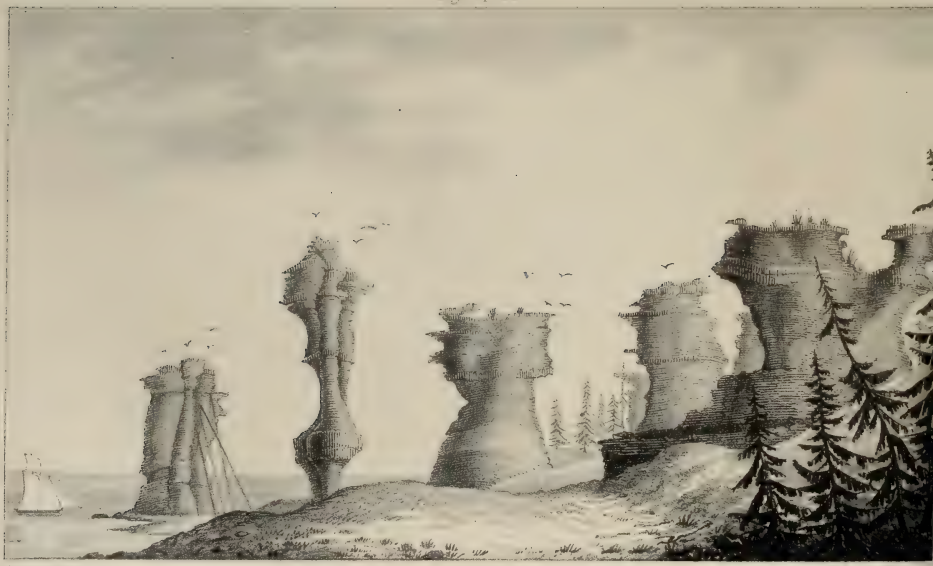
From these details we trust it will be clear, that the specimen must have belonged to the cartilaginous fishes; that it has many points of resemblance with the Squales, but still more with the Rays; but that it differs from both of these families by its peculiarly elongated head.

So far as our own limited means of observation and comparison will allow, we cannot help thinking that it will be considered a new genus by those who make Ichthyology a distinct study; and as its generic characters would be founded on parts belonging to the Squales and the Rays, we shall venture to propose the name of Squaloraia.

Fig 1 p 89

Sketch of the River and Gulf of St Lawrence

Fig 2 p 93



Natural Columns of Limestone on the East Side of Niapisca Island one of the Mingan Islands

IV.—*Notes on the Geology of the North Coast of the St. Lawrence.*

By Capt. BAYFIELD, R.N. F.R.A.S.
Communicated by G. B. Greenough, Esq. P.G.S.

[Read Nov. 20th, 1833.]

1. ON presenting a suite of specimens to the Geological Society from a long line of coast, which is scarcely more known in Canada than in Europe, being seldom visited except by fur traders and fishermen, I hope a few remarks upon the structure of the country, will not be deemed devoid of interest, though my official duties did not allow of a minute investigation.

The district between Quebec and the river Saguenay, particularly about Murray Bay, has been examined by Dr. Bigsby. The late William Green, Esq. has most ably described the vicinity of Montmorency*; and Lieut. Baddeley of the Royal Engineers, St. Paul's bay and the Saguenay river† with a minuteness and ability which leave me nothing to add. I shall therefore commence my account at the Saguenay, and proceeding eastward, describe the coast of the river and Gulf of St. Lawrence.‡

2. From the Saguenay to Pointe de Monts, a distance of 130 nautical miles §, the hills forming the coast are composed, for the greater part, of varieties of syenitic granite; and the country inland as far as the Falls of the Bersimis river, about 40 miles from the St. Lawrence, in a direction parallel, or nearly so, to the course of the Saguenay, consists of the same formation.

All the valleys and basins between the granitic hills are filled with horizontally stratified deposits of clay, sand and gravel, sometimes 200 or 300 feet thick; the clay being invariably next the granite, and the gravel generally on the surface. No organic remains having been found, it is difficult to assign to these deposits any relative age¶; but as the rivers, tributary both to the St. Lawrence and the Saguenay, have cut sections through them, future investi-

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* Transactions of Literary and Historical Society of Quebec, vol. i. p. 181.

† Ibid. vol. i. p. 79. vol. ii. p. 76. ‡ Plate V. fig. 1.

§ The distances in this memoir always mean nautical miles.

¶ Shells of species, existing at present in the estuary of the St. Lawrence, have been found in banks of similar sand and clay, as will be noticed hereafter (p. 96.).

gations may lead, by the discovery of fossils, to their true history and relative age. I am, however, averse from applying to them the term diluvial, because the regularity of their stratification would seem to be due to a cause less violent and longer continued, than is consistent with our ideas of diluvial action.

These immense deposits abound on all parts of the north coast of the St. Lawrence, which we have visited; nor are they wanting on the south coast. The soil which they supply is by no means good, but is sufficient for the growth of large pines, and may be not altogether unsusceptible of cultivation.

These formations must not, however, be confounded with the alluvial deposits at the mouths of the rivers, the latter being chiefly due to the currents undermining the soft banks, composed of the former.

Alluvial accumulations of this description, occur extensively at Pointe Mille Vaches and Port Neuf, as well as at the entrance of the Bersimis, Outard, Manicouagan, and other rivers.

The extensive Manicouagan shoals have doubtlessly been formed by the two last rivers, especially the Outard, whose course for eight or nine miles, from the falls to the sea, is through the soft strata just mentioned.

On approaching Outard bay after the time of high water, the sea was of the colour of sand, and had it not been previously ascertained that there were nearly 100 fathoms of water, we should have supposed that a sand bank existed close to the surface of the sea. When the vessel sailed into the discoloured water the effect was very remarkable. She cut through and displaced the thin stratum of comparatively fresh and discoloured water, displaying the clear blue sea beneath, and left a blue line wherever she passed. The discoloured water was ascertained to be derived from the Outard river, charged with sedimentary matter; and was so widely diffused as to cover the whole bay, and the sea for several miles.

3. The same granitic rocks, with stratified deposits in the valleys, and alluvial formations at the entrances of the rivers, compose the coast and country, from Pointe de Monts to the Seven Islands, a distance of 60 miles. The rocks constituting the Seven Islands abound with hornblende.

In the bay of the Seven Islands is a very extensive alluvial formation, elevated only a few feet above the present level of the sea at high water.

Walking inland from the sandy beach, which extends for many miles to the eastward, I counted seven parallel sand ridges in a distance of about a mile; evidently ancient beaches which formed, at different successive epochs, the margin of the sea. The number of these beaches and the nature of the wood which covers them, would seem to show, that those furthest inland are very ancient. On removing the thin covering of vegetable matter, I found in several of the ridges, clam shells perfectly similar to those which abound on the present shore. That the beaches were formed by the combined action of the sea and adjacent rivers, continued during an immense period of time, there can be no doubt; and on comparing Des Barres' plan of this bay with our survey, no appre-

ciable change appears to have taken place in the last 70 years. Whenever excavations have been made in the sand, sufficiently deep to reach below the level of the sea at low water, clay has been met with. In this respect, therefore, these undoubtedly alluvial formations bear a strong resemblance to the deposits in the valleys, basins, and hollows of the granitic hills previously mentioned, and seem to differ from them principally in being much thinner, and in occupying lower levels.

The sandy country continues from the Seven Islands to the river Moisic, a large stream which is full of sand banks, and deposits extensive sandy shoals near its mouth. It is about five leagues from the Seven Islands. About three leagues further eastward, the granitic hills, which to the westward range several miles in rear of the coast, and opposite the islands attain an elevation of 1700 feet, again approach the sea, and form the coast to the Magpie river, a distance of 60 miles.

4. The unstratified rocks of this long line of coast are arranged irregularly, in round-backed hills and ridges, often studded thickly with round knolls. Their elevation above the sea seldom exceeds 1000 feet, being about the same as that of the coast westward of Pointe de Monts. There is a much greater variety in the primitive rocks in this part of the north coast, than in any other further to the westward. Besides the genuine granite, composed of quartz, felspar, and mica, and considered comparatively rare in Canada, there is a peculiar kind of glassy felspar*, not met with by us elsewhere, which forms considerable hills and the coast for many miles. Porphyry was found at the falls of the Manitou river, and I believe this is the only locality yet observed in Lower Canada : it passes into syenite. Magnetic iron ore occurs abundantly in veins and beds, associated with the felspar rocks†.

5. From the Magpie river to Mingan, the coast is formed of the stratified, argillaceous, and arenaceous deposits, and of the alluvion of the river St. John. The soil is poor, loose, and sandy, but covered with a dense forest of spruce, with a few birch and aspen trees.

Near the river St. John, resting on the clay, is a semi-indurated sandstone in process of forming, by the percolation through the sand, of water strongly impregnated with red oxide of iron.

As my remarks have arrived near the western extremity of the Mingan islands, I shall make a few observations upon the coast which has passed in such brief review. Our boats visited every part, and ascended the rivers to their falls, yet no rocks of the transition or secondary classes were observed *in situ*. Magnetic iron ore is largely and generally disseminated, although

* I do not affirm that this is the glassy felspar of mineralogists ; but its cross fracture is highly vitreous. Its laminæ are frequently striated,—a character common in the felspars of the St. Lawrence.

† Most of the specimens in this section of the coast, were collected by my assistants Lieutenant Collins and Mr. Bowen.

we observed it in the greatest quantity in the portion of the coast which I have last described. When not seen, its existence at no great distance, was indicated by the large quantity of magnetic iron-sand on the beach, and by its effects upon the instruments, used on shore in the survey of the coast. The compass needles were frequently and powerfully disturbed all along the north coast of the St. Lawrence, not only within the limits which I have mentioned, but from Cap Tourment eastward, to the eastern extremity of the Esquimaux islands, and perhaps to the longitude of 60° west. I must not be understood as confirming the vulgar opinion, that the compasses of vessels sailing up the St. Lawrence, are affected; on the contrary, we observed, that the needles on board the Gulnare, were visibly disturbed in one or two instances only, when the vessel was not more than a mile or a mile and a half from the shore. The strongest case was off Port Neuf, where the beach contains large quantities of magnetic iron sand, and we were not more distant than $1\frac{1}{2}$ miles, yet even there the disturbance did not exceed four or five degrees; and at double the distance it became insensible.

From the Magpie river to Mingan, the granitic rocks are hid by the alluvion and the superincumbent soft strata. They pierce, however, through the sand at the entrance of the Mingan river; and afterwards appear frequently at the margin of the sea, within the Mingan and Esquimaux islands, affording opportunities, occasionally, of observing their junction with the limestone of which those islands are formed.

6. The Mingan and Esquimaux islands, 29 in number, are situated just to the northward of the 50° of latitude, and between the $64\frac{1}{4}°$ and $63\frac{1}{4}°$ west longitude, or nearly so. They range parallel to the coast from the Perroquets at the west, to St. Genevieve at the east end of the chain, a distance of about forty-three nautical miles. Their northern points are no where more than three and a half miles from the mainland, and are generally close to it; while their southern or outer points, do not extend further off the main shore than six and a half or seven miles. The most extensive island is called Large Island, being about ten miles in circumference, and Esquimaux island is not much smaller. The general character of the group is low, the highest points not exceeding perhaps 300 feet above the sea. On the north, east, and west sides, are bold and frequently steep cliffs; but on the south side the outline is low and shelving. In these and other respects, the Mingan and Esquimaux islands resemble the opposite island of Anticosti, from which, at the nearest point, they are distant about $14\frac{1}{3}$ miles.

Both the groups are entirely calcareous, and the strata dip only a few degrees to the southward, or a little to the westward of south. The limestone varies much in different parts even of the same island, being sometimes compact, or earthy, or shaly, at others imperfectly crystalline, and occasionally it passes into a calcareous sandstone, in which grains of the minerals composing primitive rocks and fragments of shells, are agglutinated by a calcareous cement.

The small columnar or prismatic structure was several times observed, precisely similar to specimens, which I have seen, from the limestone of Kingston in Upper Canada. At Betchewun harbour, between Hunting island and the main, we noticed parallel, semi-cylindrical groovings in the limestone, of various dimensions, and diagonal to the direction of the strata. At first we imagined they had been produced by the attrition of boulders drifted by running water; but further observation induced us to think, they were due to structure.

There is plenty of stone fit for the common purposes of building, but we saw none adapted for ornamental architecture. Many of the strata are very hard, and although I do not think very large blocks could be procured, yet the stone appears of excellent quality and stands the weather well.

Masses of flint were found several times on the beaches, and nodules of chert are not uncommon in the limestone, particularly at Harbour island, Mingan, where the nodules are evidently derived from organic remains. I found Orthoceratites, Encrinites, &c., completely converted into chert, but with their shapes perfectly retained. In the greater number of these nodules, however, the form of the organic body had been nearly obliterated, and in many cases it was not perceptible. No metallic minerals were found in any quantity, but traces of lead, zinc, copper, and iron were observed in all the islands.

In some places there are few or no organic remains, but they are generally abundant. The most common is a species of Ammonites, next Orthocera, and both were seen occasionally of very large size. Encrinites and corals were also numerous, and several kinds of bivalve shells. Unchambered univalves were very rare, as we found only four or five specimens of two kinds. Many of the fossils are similar to those in the limestones of Anticosti, Cape Gaspé, the neighbourhood of Quebec, Kingston in Upper Canada, and the Manatoulin islands in Lake Huron, a circumstance which induces me to think, that these limestones are of the same age. From the organic remains, and all the strata being carbonaceous or bituminous*, I infer also that they are analogous to the mountain limestone of England.

7. On most of the Mingan islands the limestone cliffs have been broken by the waves into columns of various shapes, frequently resembling flower pots, or arched and perforated rocks, &c. Plate V. fig. 2.

It is extremely worthy of remark, that there are limestone columns and beaches of limestone shingle, or gravel, exactly similar to those now forming, high up on the islands, from thirty to sixty feet, at the lowest estimation, above the present level of the ocean at the highest tides, and far back among the trees, in rear of the present sea beach.

One of two hypotheses must, I think, be adopted to account for these appearances:—either the general level of the ocean has fallen or the land has risen. If the latter supposition be the correct one, and I think it by far more probable than the former, the raising of the land cannot have been violently accomplished, for the strata are not disturbed, nor the columns thrown out of the perpendicular; neither can it have been done all at once, but by a succession of gentle movements at different epochs, acting uniformly over a great extent of country at the same time.

This reasoning is founded upon the following appearances and observations:—The land cannot have been raised by one great operation, because the columns and beaches are at different levels on the same island; and because on groups of flower-pot shaped, or other columns, there are

* The limestone of the Manitoulin Islands is occasionally very bituminous. I have found Orthoceratites from which, when broken, the bitumen flowed like tar.

marks of the sea having remained for a considerable time at different levels; to which parallel beaches of limestone shingle correspond.

I imagined, at first, that the peculiar shapes of these natural columns might be the effect of atmospherical agents, and the unequal hardness and consequent power to resist that effect, in the different alternating strata of limestone. Observation however soon convinced me, that these agents are incapable of producing such effects. They may and do wear away the cliffs rapidly, aided by the expansive power of freezing water, in a climate whose winter temperature is so low; and if the cliff be composed of strata of a nature to be unequally acted upon, it may be undermined, or several projecting ledges may be left, and these may be divided by natural fissures, so as to cause the face of the cliff to assume a variety of shapes; but a talus is soon formed which protects it from further destruction from this cause.

The action of the atmosphere alone, therefore, cannot form groups of isolated natural columns or perforated rocks, and carry away the debris or arrange it in parallel beaches of waterworn fragments, whose levels correspond with those at which the columns remain, or to the parts of those columns which appear to have been worn slender by the long continued action of the waves. But if we attend to what is going on at present on these islands, we shall have little difficulty in deciphering the memorials of the past. We see columns of limestone, evidently the ruins of former cliffs, assuming the various shapes of flower-pots, towers, arches, &c., and standing on the gently shelving limestone, laid dry only at low water, and at a short distance from the permanently dry shore. They are worn away by the waves acting upon a space which depends upon the rise of the tide, until they become very thin at the mean level of the sea. It is thus that they so frequently assume the shape which has led to their being termed flower-pots. The limestone gives way to this incessant washing, in angular fragments, which, after undergoing attrition in the surf for some time, are finally deposited in beaches of shingle, upon the shelving limestone, at an elevation corresponding to the highest rise of the tide. Such is the process at present, and the columns, with beaches of corresponding elevation, were observed to be forming in every favourable situation.

Now the columns which occupy levels far above the reach of the sea at present, are not only exactly similar in appearance and shape to those which are forming, but are accompanied by beaches of limestone shingle, more or less waterworn, and of corresponding elevation to the worn stems or shafts of the flower-pot columns.

These appearances, I think, can only be explained by allowing, as before stated, either that the land has been raised, or that the level of the ocean has fallen. In either case the changes of level have been only a few feet at a time, with long intervals between, as is indicated by the wearings of the columns, which must have required a long period of years, and by the succession of the beaches one above another*.

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* There is one more indication which was observed by Dr. Kelly, R.N., in the harbour of Quarry island. He there found the limestone perforated by Lithophagi at a height not reached by the sea at present, excepting perhaps in very high spring tides. The harbour is so well sheltered that there is never any surf to wash this perforated ledge of limestone when the water does not otherwise rise to it. Considering all the circumstances, it is *possible* that the sea may attain the height of these perforations, and remain at it for an hour or two at a time, during two or three tides in a month; but it is probable that in the summer, when there are seldom gales to cause extraordinary high tides, the ledge may not be reached by the water for two or three months in succession.

Lithophagi could not possibly live in such a situation, perfectly dry and heated by the sun for weeks together. We frequently found masses of limestone on the beaches perforated by Lithophagi, the shells of which remained in the cavities, but they appeared to have been washed up by the surf, and we have every reason to believe that these animals live, either constantly submerged, or in situations which are dry only for a short time during each tide.

That several similar elevations of the land or depressions of the sea would be necessary to account for all the appearances on the Mingan islands, may be inferred from the following.

We ascended several times cliffs at the water's edge, and on their summits, thirty feet above high tide level, we found beaches of limestone pebbles, more or less rounded and water-worn, which were continually falling down as the cliffs gave way beneath them, by the undermining of the waves or of the elements. In rear of the first beach I counted five or six others, each higher than the preceding, and all more or less covered with vegetation, and the higher ones with trees. The highest was sixty or seventy feet above the sea. Appearances exactly similar have been observed on Lake Huron, and described in a paper published in the Transactions of the Literary and Historical Society of Quebec*.

Most of the flower-pots and other columns were from fifteen to thirty feet, but some exceeded forty feet in height above the plateau of rock on which they stood. They were frequently arranged in lines upon a terrace of limestone, precisely as they are forming at present, at the water's edge, out of cliffs which are washed by the waves.

In those columns which have been successively worn or scooped out by the waves at different levels, it is not unworthy of remark, that the part so worn generally corresponds, in perpendicular height, to the rise of the tides at present; thus leading to the inference, that although the level of the land or sea must have changed to produce the appearances described, yet that that change has not been sufficient to materially modify the circumstances, upon which the height of the tidal wave, in an estuary, depends.

A faithful record of the powerful effect of natural agents, in the present day, will best enable us to judge of the past. It is, on this account, that I mention an instance of the partial destruction of these rocks, during an absence of ten months from the Mingan islands. In the autumn of 1831, we noticed several remarkable flower-pot columns on the east side of Mingan island, some near the water, others considerably above its level. We were familiar with their shape and appearance, having looked at them frequently through our telescopes, and used them as stations in the trigonometrical survey. Lieutenant Collins had also examined them closely. On our return, in June, 1832, we found the heads of several of these flower-pot columns broken off by an agent, traces of which still remained. An immense bank of ice and snow was on the island, in rear of the broken columns, and was not totally dissolved on the 17th of July, when we last saw it. This had doubtlessly been forced up during heavy easterly gales, and the pressure of the ice had broken off the heads of the flower-pot columns.

This change of level appears to me of so much interest, that I must add a few more remarks respecting it, before I proceed with my description of the Mingan islands.

In almost every part of the estuary of the St. Lawrence, we observed other appearances which we could also account for only by supposing either that the level of the sea, in the estuary and gulf, has fallen, or that the land has been elevated. In many bays and entrances of valleys near the sea, are sandy terraces at different levels, corresponding on opposite sides, and so shaped that it was impossible to resist the idea, they had once formed the margin of the ocean. I have mentioned (2. p. 89), that the rivers have cut sections through the soft strata of clay, sand, and gravel, and that the detritus which they bring down, is principally derived from these formations. I have also alluded to the resemblance between these more ancient strata and those of undoubted alluvial origin, which have been formed and are still forming at the mouths of those rivers.

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* Vol. i. p. 6.—1829.

The following additional remarks will show that resemblance in a stronger light, and have reference to the phænomena which I have described upon the Mingan islands.

Sand and gravel are the most abundant materials brought down by the rivers, and are arranged around and off their entrance, forming low points and sand bars, which rest upon clay, at, or a few feet beneath the low-water level. Many of the rivers bring down argillaceous matter also, and this lighter material is carried further by the streams, and deposited in the comparatively still water without their entrance. But as these sandy points have extended further into the sea, they have covered the argillaceous matter previously deposited, and hence it is, that we always find clay under the sand in these alluvial formations. The streams, of course, cannot place these materials above their own level or that of the sea at high water. Sand shoals, which are dry every tide, are first formed, and the action of the winds and waves does the rest. The tendency of these sands to arrange themselves in strata, was frequently observed, where small streams had cut sections through the beaches.

In walking inland from the entrances of these rivers, we pass over low flat ground, composed of sand hills and sand beaches, covered first with grasses and shrubs, and further inland with trees. The immediate banks of the river are low sand cliffs, having their bases washed by the stream. Next succeeds a sandy terrace, rising abruptly twenty or thirty feet. Directly opposite, on the other side of the river, is a similar terrace, the cliffs on each side corresponding in elevation. Another flat succeeds, and frequently a second, and sometimes a third, the last being a hundred feet or more above the sea. If we attend to the sections cut by the streams through these terraces, we find the cliffs horizontally stratified or nearly so, the lowest stratum visible at the water's edge or a few feet above it, being clay; but if we ascend the river sufficiently far, we find that this lowest stratum of clay occupies a level above the present ocean, and in situations where there are no gorges of valleys, which we can imagine so closed up, as to raise the waters within to a higher level.

If, therefore, these ancient terraces and soft strata are alluvial deposits, analogous in their mode of accumulation to those forming at present, then the relative levels of the land and sea have certainly changed, let the cause be what it may.

Near the Falls of the Bersimis river, Mr. Bowen found the clay, under the sand, in thin strata, semi-indurated, and having a tendency to break into rhomboidal fragments:—a circumstance, which I shall have to mention again in similar formations.

Among other proofs of a change in the relative levels of the land and sea in the estuary and Gulf of St. Lawrence, is the bank of semi-indurated sand and clay at Beauport, near Quebec, full of shells, of species existing in the estuary.* This bank is far above the present level of the river. We also noticed a bank, apparently an ancient beach, containing similar shells, at the entrance of the Rivière du Loup, on the south side of the St. Lawrence, and about sixty feet above the present high water mark. It rests on the greywacke and slate rocks.

Several other instances of banks of shells at high levels, on each side of the river and estuary, have been mentioned to me, but as I have not visited the localities, I merely state the circumstance as of frequent occurrence. I believe there is much in the valley of the St. Lawrence to reward the researches of the geological traveller, who may turn his attention to these comparatively recent deposits; and I am surprised that they have not attracted the attention of those who have visited the St. Lawrence, and written on its geology.

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* The St. Lawrence is perfectly fresh thirty miles below Beauport, yet the species of shells in the bank mentioned, are all, or at least by far the greater number, inhabitants of salt water. They are also frequently perforated by a marine boring worm which also lives in the estuary and gulf.

I shall describe one more proof of a change of level, which came under my own observation, at La Petite Rivière, near St. Paul's Bay.

Between Cap Maillard and Cap de la Baie, near Quebec, the hills of gneiss, abounding in garnets and magnetic iron ore, recede so as to form an irregular crescent, the interior of which is filled with a low alluvial formation, not more than 20 feet above the rise of the highest tides. This formation consists of clay thinly covered with sand, and contains many boulders principally derived from the adjacent mountains. The clay is in thin, horizontal strata, and semi-indurated, so that it can be raised in large pieces, which are easily broken by the hand into rhomboidal slabs, from six inches to a foot in diameter. It abounds with impressions of rushes, partly filled with and stained by, brown oxide of iron, derived, by filtration, from the neighbouring hills. It contains also occasionally clam shells, similar to those existing in the river.

Everything indicates a quiet deposition, when the waters of the river had a higher relative level than at present. On this alluvial flat, the farms of La Petite Rivière are situated. At present the St. Lawrence is fast destroying this alluvial formation, not by a rise in its waters, but by a change apparently of the direction of the tidal currents, depending perhaps upon the formation of shoals in other adjacent parts of the river. Every high tide, accompanied by a strong north-east gale, washes away large portions of the fields, so that the inhabitants are driven to seek for fertile soil among the hills. This gradual destruction has been going on for many years, as I was informed by a Canadian, ninety years old, who had resided there from his youth. He pointed out to me large boulders, now lying on the shoals, dry at low water, which he ploughed around thirty or forty years before.

The old church of La Petite Rivière has been washed down by the waves, and the present one is likely to share the same fate, at no very distant period. The old church of Les Eboulemens which was built upon a similar formation, has been also destroyed in the same manner. The wall next the water has fallen, having been undermined by the waves, and trees now grow within the other three, their roots assisting to preserve the ruin.

Such are the indications of a change of level which have come under my own observation. I must now conclude this subject with the following remarks.

I cannot affirm positively that the heights of the terraces, in valleys and bays of the main land, are exactly the same as those of the ancient sea beaches of the Mingan Islands, but there appeared a very near agreement.

It is certain that terraces of the same height extend over very large areas, and it appears extremely probable that the same agent may have simultaneously elevated these ancient alluvial terraces, and the ancient beaches and natural columns of the islands.

It is not easy to imagine any alteration in the level of the sea, within the Gulf of St. Lawrence, without an equal change in that of the Atlantic Ocean. It is to volcanic agency, therefore, we must look for the probable cause of the appearances which I have endeavoured to describe; and the probability of this inference is manifested by the fact, that the great agent alluded to is still felt. Shocks of earthquakes are frequent at Murray Bay, Les Eboulemens, St. Paul's Bay, and the adjacent country, of force sufficient, at times, to split walls, throw down chimneys, &c.*

The earthquake of 1663 is said to have lasted six months, and to have caused land slips and other changes in the face of the country. It is to be regretted that there are no clear and detailed

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* For an account of the earthquake of 1791, see Lieut. Baddeley's Notes on the Geology of St. Paul's Bay, Transactions of the Literary and Historical Society of Quebec, vol. ii. p. 83, *et seq*, 1831.

accounts of this event; but it is sufficient for the object which I have in view, to mention the fact of its occurrence. Frequent shocks have been felt every year since, though less violent.*

I must now return to the description of the Mingan Islands, from which I have digressed so greatly in pursuing a subject, which I believe, had not been before touched upon by any author on the geology of the shores of the St. Lawrence.

8. The Mingan and Esquimaux Islands have very little soil. The limestone, where not bare, is covered by limestone shingle or gravel, or by decayed vegetable matter resembling peat. Hence the islands may be considered barren in an agricultural point of view. The timber also is small, and principally spruce, with a few birch and Canadian poplar or aspen trees. Blue or whortleberries, cranberries, and several other wild fruits are in abundance.

The stream of the tides is not very strong among these islands, seldom exceeding a mile an hour, except in narrow channels, where it sometimes attains a rate of two and a half. The rise is about seven feet in ordinary spring tides, and about three feet in neap tides.

9. The mainland is composed of low granitic hills. St. John's Mountain, some miles in rear of the entrance of the river of the same name, and 1416 feet above the sea at high water, is the loftiest point in the neighbourhood. There is land about 1000 feet high, opposite Quarry Island, ten miles east of Mingan, but towards the east end of the chain of islands the mainland is very low, the hills being far back in the country.

The granitic rocks, a few miles to the eastward of Mingan, are composed

* In July, 1831, the shocks at Murray Bay were more than usually severe. The walls of the church, it is said, were split, stone ovens and chimneys were thrown down or displaced, and a rocking motion was communicated to the houses. Many of the inhabitants were so alarmed as to seek safety on board of vessels in the bay, where the shocks were also felt. This earthquake was experienced at Beauport, nearly ninety miles to the south west: how far it extended in the opposite direction is not known, there being no inhabitants. It was also felt on the south side of the St. Lawrence, at the Rivière Oulle, and at St. Roques: how far it might have been felt to the northward of the St. Lawrence is also unknown, the country in that direction being uninhabited. An intelligent lady, who was then at Murray Bay, informed me that the shocks were always preceded by a subterranean noise, resembling distant thunder, which approached from the northward, and appeared to pass under the houses. When this noise seemed immediately beneath the house, a heavy shock was felt, as if the house had received a heavy blow; this was succeeded instantly by a rocking motion of the building and undulation of the ground, producing a sensation not unlike sea-sickness. The earthquakes have been, in general, accompanied or succeeded immediately by squally weather, sudden gusts of wind, &c. Shocks were felt very frequently during the months of March and April, 1833.

of red felspar, quartz, and hornblende, the felspar predominating. They are succeeded to the eastward, opposite St. Geneviève Island, by true granite, consisting of red felspar, white quartz, and black mica.

The connexion of the granite and limestone is well shown at several points. On the east side of Pillage Bay and Mount St. Geneviève, 332 feet above the sea, the limestone rests immediately upon the granite in nearly horizontal strata. Opposite St. Geneviève Island is a round, isolated and precipitous hill of limestone, which rests also upon genuine granite; and other similarly shaped hills of limestone, with mural sides, but smaller and of less elevation, occur in the same vicinity, resting likewise on granite.

The country for many miles inland is composed of low granite mounds, the intervening hollows being filled with stagnant water, peat, or other vegetable matter.

The great irregularity of the bottom of the sea among these islands, as indicated by the sounding lead, strengthens the inference from analogy, that the islands rest upon granitic hills, in the same manner as the isolated hills of limestone mentioned above. Some of the rocks and shoals, under the sea, are as precipitous as the islands above it, having thirty or forty fathoms of water close to them. It does not seem difficult to imagine, in this respect as well as in others, a resemblance in these ancient calcareous formations, to those which are forming at the present day, on the summit of submarine hills in tropical climates.

Neither limestone nor any other transition or secondary rock, was met with to the eastward of St. Genevieve.

10. The coast thence to Cape Whittle, in the longitude of 60° west, and latitude 50° 10′ north, is composed of varieties of granitic rocks, in which, contrary to what has been observed of the granites of Canada, hornblende is a rare constituent. The coast is of very moderate elevation, possesses few remarkable features, and cannot be distinguished from the deck of a vessel, at a distance exceeding four or five leagues. It is broken into bays and inlets, and lined with innumerable small islands, rocks, and reefs*.

The granite of the main and islands is almost everywhere covered with peat, full of stagnant ponds of dark bog-water. Trees become more and more scarce as we proceed to the eastward, till at last they are almost exclusively confined to alluvial formations of sand and clay, which are of rare occurrence, and, excepting at Natashquan, of limited extent.

It is not my intention to describe mineralogically the different granitic rocks which occur on this coast. Metallic minerals, with the exception of

* Few places can be imagined more barren, dreary, and desolate, than this coast, or more gloomy than the climate in which it is situated. It is girded with ice, and covered with snow, from October to June, and is wrapped in dense and cold fogs for more than two thirds of the remainder of the year: yet it teems with life in the summer season.

iron, appear to be rare: native copper, associated with epidote, was met with by Lieut. Collins in only one instance, about five leagues eastward of St. Geneviève, and in very small quantity: schorl and traces of iridescent or Labrador felspar were observed in the same locality: and hypersthene, or Labrador hornblende, was often noticed. I sometimes imagined, that I could perceive an imperfect stratification in these granitic rocks, but it may have been the result of structure, and upon the whole I regard them as unstratified. They are traversed occasionally by trap veins, insignificant in size, when compared with the immense dykes of the Lake Superior granites, which appear to have poured forth such extensive beds of greenstone and amygdaloid, an operation which probably took place under the ocean, from the frequent association of beds of rolled masses of porphyry, cemented by a paste of the same material as those igneous rocks.

Six rivers of considerable magnitude, besides smaller streams, enter the Gulf of St. Lawrence between St. Geneviève and Cape Whittle, namely the Nabesippe, Aqwanus, Natashquan, Mushquarro, La Romaine, and Coacoatcho, and are respectively distant from St. Geneviève 33, 38, 50, 79, 97, and 110 miles. They are all unnavigable in consequence of shallows or rapids, commencing a short distance within their entrances. The Natashquan, which flows into the gulf directly opposite the east end of the Island of Anticosti, is the largest, and is remarkable for the great quantity of sand which it discharges into the sea; and its wide bed, like that of the Moisic, is full of sand-banks. Its mouth is on the west side, and near the southern extremity of an alluvial promontory, the materials of which it appears to have brought down during the course of ages.

This alluvial accumulation, formed evidently by the combined action of the river, tides, winds, and waves, is the most extensive which we have seen on the north coast of the St. Lawrence below Quebec, unless that of the River Moisic be equally so. Its area is forty-eight square miles, and it has completely covered the low granitic islets and rocks. Thus, it has not only interrupted the direction, but also completely changed the character of the coast for the distance of twenty miles, substituting cliffs of sand, or sandy clay, with a fine sandy beach in front, for innumerable islets, rocks, and reefs.

11. To the southward of the Mingan islands and along the coast of Labrador, as far east as we have yet examined, are extensive banks having from twenty to forty fathoms of water, and composed of gravel, sand, and immense quantities of broken shells. In sounding over many hundreds of square miles, fragments of shells, and occasionally of coral, were brought up, by almost

every cast of the lead. Indeed there is nothing more remarkable than the immense quantity of calcareous matter, supplied by testaceous and crustaceous animals, in the Estuary and Gulf of St. Lawrence. The beaches were occasionally composed almost exclusively of small fragments of shells. In depths exceeding fifty or sixty fathoms the bottom was usually mud.

Another fact which forced itself upon our notice, was the frequent occurrence of the bones of cetacea along the shores, and probably, for the most part, of animals destroyed by the whalers. They were frequently observed on the low alluvial flats at the entrances of rivers, and were sometimes accompanied by marine, freshwater, and terrestrial testacea, together with the bones of quadrupeds and birds*. In such situations these remains can scarcely escape being carried away by freshets, at the periodical melting of the winter's snows, and being promiscuously deposited in the mud and sand on the bars of the rivers. May we not attribute to similar combinations of circumstances, the admixture of marine with freshwater, or terrestrial remains, in more ancient formations, where no other circumstances appear to contradict such an inference?

12. I shall close this paper with a few observations intended to complete a very rough outline of the geology of the river and estuary of the St. Lawrence below Quebec.

All the islands on the south shore of the St. Lawrence above the junction of the Saquenay, and the few below it, together with the whole of the south coast as low down as Cape Rozier, are composed of alternating strata of greywacke and slate, dipping to the southward at angles varying from about 30° to nearly 90°.

Above Cape Chat the hills which bound the valley of the St. Lawrence to the southward, are some miles from the coast, but at Cape St. Anns, a few miles below Cape Chat, they approach the sea, and give a mountainous character to the remainder of the coast as far as Cape Gaspé.

We have ascertained, by actual observation, that the hills next the sea, as high as 1000 or 1500 feet, are of greywacke and slate. There is a higher, parallel chain a few miles back, which, in one part, is nearly 4000 feet above the sea, being the highest land in Canada or the United States, excepting the mountains of New Hampshire. This higher chain has been said to be primary and the outline or contour of the hills which compose it, lead to that inference. I doubt, nevertheless, of this being the case, because I have observed

* On the sands at the entrance of the river at Mingan, I saw the whole of these remains together.

that the dip of the transition rocks is not changed by their immediate vicinity, and because other hills of considerable elevation and of the same appearance, have been ascertained to be of sandstone. I am inclined to think that they will be found to be of greywacke, or of secondary rocks overlying that formation.

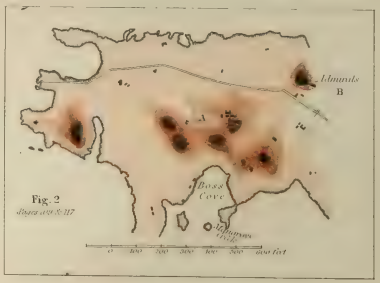
The south coast of the St. Lawrence follows the direction of these hills, curving to the southward as we proceed to the eastward; and it is worthy of remark, that the direction of the strata seems to follow that of the coast. The greywacke series terminates on the coast at Cape Rozier, and is succeeded by conformable strata of limestone, dipping at an angle of about twenty-five degrees to the south-west, and forming the remarkable and precipitous headland of Cape Gaspé.

This limestone contains Encrinites, corals, Orthocera, Producta, and other shells similar to those found in the limestones of Anticosti and the Mingan and Esquimaux islands. It contains thin veins of galena and blende, but not worth working.

This limestone, which I conceive to be the younger transition, is succeeded to the southward, by a series of alternating sandstones and shales, the strata of which are much disturbed, but preserve a general, conformable dip to the south-west. Both the sandstones and shales are highly bituminous, and petroleum springs have been found in the neighbourhood.

Still further to the southward, at Percé, near the entrance of the Bay of Chaleur, conglomerate, sandstone, shale, and limestone were observed, alternating in conformable strata, and preserving the same general dip as before mentioned. Among these, coal is said to have been discovered, thus indicating the approach towards the extensive coal formation of New Brunswick. It is probable that we shall learn more respecting the formations of this neighbourhood, when we survey the southern part of the gulf.

I must now close the paper with a hope, that the desultory and imperfect nature of the information which it contains, will be excused, when it is considered that the remarks, here given, were the result of those casual observations, which we were enabled to make, during the prosecution of our professional duties.



PLAN OF THE BERMUDAS.

by Lieut. Nelson R.E.

The Outline of the Reef is sketched from the usual authorities

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V.—*On the Geology of the Bermudas.*

By RICHARD J. NELSON, Esq. Lieut. R.E.

Communicated by George Bellas Greenough, Esq., P.G.S.

[Read April 23, 1834.]

HAVING been stationed at the Bermudas, at different periods between the years 1827 and 1833, I made a series of notes on the peculiarities of their structure, and the following memoir is the result. Much information was derived from sources which are no longer accessible, such as the aspect and arrangement of the strata, presented by large excavations made during the progress of the works, conducted by the Royal Engineer Department, and are either no longer in existence, or are masked by *revêtements**.

Though the Bermudas are barren of mineralogical interest, they have yet claims to attention in the striking lithological resemblance, which some of their rocks bear to chalk and other secondary limestones ; and I hope that my descriptions may afford a clue to the origin and nature of those formations. Conceiving also that a comparison of the Bermudas with the coral islands in the Pacific, described by Kotzebue, might be instructive, I have given references to those passages in the work of that author, which present any analogy or important variation.

The Summer Isles, Somers' Islands, or Bermudas, (see Plate VI.) consist of a group of about 150 islets, lying within a space of fifteen miles by five, and containing altogether nearly twenty-one square miles. This singular little archipelago is situated very near, and conformably to, the south-east side of an elongated ring of what are commonly called† coral reefs, and rudely approaching the shape of an ellipse, twenty-five miles long by thirteen broad. The direction of the group, as well as that of the major-axis of the reef, to which it is parallel, is about north-east and south-west. Although of a more regular form than any exhibited by Kotzebue, it bears a considerable

* The collections formed by the author have been presented to the Museum of the Geological Society of London, the United Service Museum, the Berlin Academy, and the Cabinet of Sir John Tilden.

† "Commonly called." This qualification is explained in pages 105 and 116, where it is shown that many reefs are formed by Serpulæ.

resemblance to the Otdia, or Romanzoff islands. The principal islands are generally separated by channels, from ten to twenty feet deep, and many of the spaces between the smaller islands are fordable. The depth within the reef rarely exceeds twelve or fourteen fathoms*.

The highest land is at Sear's Hill, immediately above and to the westward of Harrington Sound. Its summit may be about 260 feet above the sea; that of Gibbs' Hill is 245 feet. These and all the other numerous small eminences, have much the appearance of sand hills in shape, and chalk downs in colour.

The whole of the islands are composed of calcareous rocks, derived from comminuted shells and corals; and vary in texture from loose sand to a hard compact limestone, susceptible of a good polish. The varieties are irregularly associated, and without any order of superposition†.

From the saddle-shaped sections observable throughout the islands, the strata have evidently been accumulated round numerous and contiguous centres: the question as to the agency to which this is attributable, will be discussed in its proper place‡.

The bottom of the basin consists of coral reefs (which do not appear above low water mark, except at spring tides) and calcareous sand, the last being associated with considerable tracts of chalky ground, in which the best anchorages are found. I have met with this chalk likewise as a constituent of the rock, lying irregularly among its beds in a soft state, or lining caverns,

* Kotzebue describes the coral islands of the Pacific as consisting of circles of islets, amounting in some instances to sixty, and surrounding a lagoon. The intervals between the islets are dry at ebb tide; but the centre of the lagoon generally varies in depth from thirty to thirty-five fathoms, the soundings gradually decreasing towards the margin. In those seas, where the constant monsoons prevail, the windward side of the island first rises above the level of the water, being composed chiefly of blocks of coral and fragments of shells thrown up by the waves. Voyage to Behring's Straits, vol. iii. p. 333 : 1821.

In Kotzebue's chart of the Radack and Ralick chains, there are exceptions to the rule of the islands being exactly on the windward side. Bermuda is not subject to any very regular wind; perhaps more to the south-west than any other. Currents have been likewise observed setting towards the island from the north-east, though I cannot say whether permanently or not; or whether the gulf stream possesses any influence in those parts. The harbours at Bermuda are not always so particularly 'calm'; and it is only in certain points that they are absolutely 'secure'.

There are several entrances to the interior practicable to vessels of about twelve feet water; but only two for ships of any size, the south-east passage, and that of the north rock, both very intricate.

† See Kotzebue's similar account of the structure of coral islands, Ibid. vol. ii. p. 357; vol. iii. p. 141; and in particular the alternation of beds of sand and limestone, Ibid. pp. 144, 145.

‡ See Kotzebue, vol. iii. p. 144, for similar conformations in the strata.

but seldom exceeding a few square yards in surface, and a few inches in depth*.

The islands are covered with about a foot of dry, red earth, containing vegetable matter, and behaving before the blowpipe exactly like common aluminous earth.

The only minerals which have been noticed, are small pieces of oxide of iron, of very questionable origin; menaccanite, found near the ferry between St. George's Island and Bermuda or Main Island; arragonite, and a minute quantity of manganese in the red earth.

Unless immediately after a heavy shower, or when a fine cool morning acts as a refrigerator to the evaporation of the preceding, sultry day, or in the immediate neighbourhood of the marshes, the dew, though it does fall in all places, is scarcely perceptible, owing to the porous nature of the rock†.

Having thus briefly noticed the coincidences between the structure of the Bermudas and the coral islands of the Pacific, I will mention an instance which indicates a difference. Kotzebue says,

"The reefs at Otdia consist principally of dark coral, which is mixed with but a little red; at low water the rocks are visible for about two feet, which was the case when we used the stream anchor; but all was soon covered by the rising tide. We had at a small distance from it forty fathoms' depth, but which increased a little further so much that we could find no bottom‡."

This answers to the description of our serpuline reefs, but not of those which owe their origin to zoophytes. The observation was made by Kotzebue, and seems to have been overlooked by Chamisso. It is proper to add, although the animal of the Serpula can live for many hours out of the water, yet that of most corals, on exposure, deliquesce in a few minutes into a slimy liquid.

The tides at Bermuda average about four feet six inches; and at low water the serpuline reefs stand about two feet above the surface. The variations in the outside soundings, are by no means as rapid as in the South Sea coral islands.

* Capt. Kotzebue says, "The greatest depth in the whole group (Capeniur) was twenty fathoms. In our anchorage place we had only six fathoms: the bottom consisted of white clay, a circumstance which we had not met with in any other group." As this clay is noticed by Captain Kotzebue, and not by either of the naturalists, it is very probable that the word 'clay' was used without respect to its more specific meaning, as restricted to aluminous earth. The local name for the Bermudian chalk, is pipe-clay.

† Kotzebue says (vol. ii. p. 45.) "no dew falls," and (vol. i. p. 152. vol. 3. p. 145.) "the inhabitants depend on rain for their supplies of fresh water; of which, however, there is no want in the larger islands, as it rises in pits dug for the purpose."

‡ Vol. ii. p. 16.

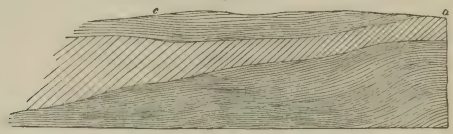
Geological Details of the principal Islands in Geographical Order*.

St. George's Island.—The strata dip southward with considerable uniformity along the southern and eastern shores, which are protected from violent attacks of the sea by St. David's, Smith's, and Longbird islands; and by the reefs which bound the intricate passage into Murray's Anchorage.

The north side is exposed, throughout its whole length, to the fury of a sea which has had, within the area of the north reef, a distance of seven or eight miles, sufficient space to re-accumulate its destructive energies; and exhibits in the cliffs the saddle or dome-shaped structure, (variously exemplified in figs. 1 and 2,) the lines of lamination dipping towards every point of the compass. In one or two instances, the summits of what were once internal hills, are bared, and within a few square yards the coats of this nucleus range round it with perfect regularity. As might be expected, this north side consists, in a great measure, of abrupt cliffs, and landslips brought down by the undermining of the waves.

Fig. 1. Sections at the summit of Retreat Hill.

Fig. 2.



This section is at right angles to Fig. 1, *the points* (*a*) *coinciding.*

The sandstone on the summit of some of the hills, is scarcely tenacious enough to hold together; but from Mullet Bay to the ferry, on a level of not more than twenty feet above the sea, the rock suddenly becomes a very hard, fine-grained or compact limestone, in which scarcely a vestige of organic structure is visible.

Just above high-water mark, along a considerable portion of the south side, is a stratum of calcareous sand, about six feet thick, apparently a distinct deposit from the rock above it.

Vertical crevices abound, filled with a substalagmite† much harder than the rock. In some places the arrangement of these cavities resembles that of veins in old slate or limestone. Where the partitions stand comparatively unimpaired by the weather, their planes constantly intersect one another, and thus form reticulations, once filled with the soft sandstone. In all cases the veins are younger than the crevices, from whatever cause these last may have originated.

St. David's.—Like St. George's, this island consists of a low, irregular belt of hard limestone

* Map, Plate VI.

† I have employed this word to designate uncrystallized calcareous incrustations and deposits; whilst I have retained the word 'stalagmite' to describe such as are crystallized.

which commences in the centre of the north side, and continues westward, through Stock's Point, till it appears, as above noticed, at Mullet Bay.

Cooper's Island.—Here I have remarked nothing, except the supposed cast of a tree at the south-east point. It will be referred to under the head of 'Organics.'

Longbird Island—Affords an excellent horizontal section along the south side of strata, deposited in irregular undulations, and not contorted by any subsequent disturbance.

Nonsuch, Castle, and Goat Islands.—As far as interest depends on variety, these possess but little. They, however, exhibit the frusta of the saddle-shaped structure, which may often be traced from one island to another, though frequently separated by considerable intervals.

Bermuda, or the Main Island.—The description given of the north side of St. George's answers in all respects to that of the whole of those coasts which are exposed to the ocean. On the south side, the sand has made several encroachments, but only at Elbow Bay, with any great success.

This sand tract will be more minutely described under 'encroachments;' but I may here remark, that wherever the rain, in effecting its escape, has scooped channels in the slope of this sand, their sides and bottom are lined with substalagmite of about one eighth of an inch thick. This is not peculiar to Elbow Bay, for, generally, wherever the sandy rock has been exposed in a hill side, it will be found coated with this incrustation.

Westward of Hungry Bay, the rock assumes a somewhat uniform character. A stratum of sand, corresponding to that on the south side of St. George's Island, begins to show itself at about the centre of the island, continuing thence for a few miles westward; but in both instances there seems little difference in age between these sand beds and the strata above them, as the same shell, an helix, is found in abundance at all levels.

Fig. 3.

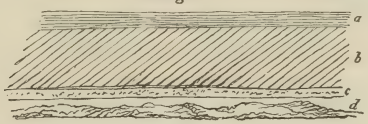
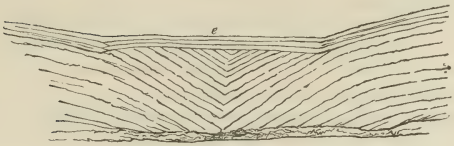


Fig. 4.



Figs. 3 and 4 are general sketches of the cliffs along this south coast, especially between Elbow and Whale Bays.

Fig. 3, *a*, *b*, ordinary rock, friable calcareous stone occasionally appearing, as under *e*, fig. 4, with faults, where the sand stratum (*c*) has been washed away, and thus assisted the sea in strewing these coasts with landslips and huge blocks. Fig. 3. *d*, Apparently a very new deposit, from the looseness of its texture, and its containing perfectly recent marine shells; it seems to be merely a covering to the regular rock lying under *c*.

Somerset.—One of the prettiest islands, has but little to attract the attention of the geologist.

Ireland.—The position of this island is similar to that of St. George's; but owing to its narrowness (in one place, Cockburn's Cut, the breadth being hardly fifty yards) there is little room for the development of the saddle-shape; although I conceive that a reference to figs. 5, 6, will show that however now truncated, it once existed.

Fig. 5, section east end of the island, and Fig. 6, section at right angles to *a*, Fig. 5.

Fig. 5.

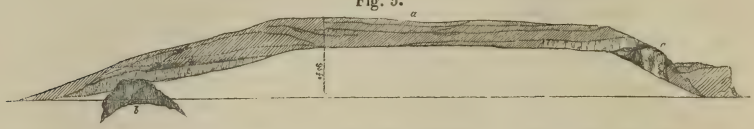
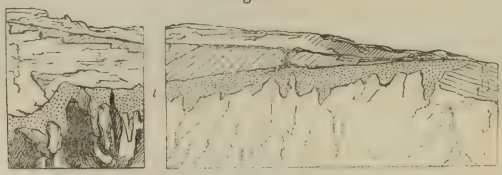


Fig. 6.

b. a. f. i. h. medium stone. *c.* soft sandy bed passing into *b. g. d.* *d. e. g.* hard rock.

Fig. 7.



Caverns under stratum *d*, fig. 5, and covered with red earth *l*.

Although, as before stated, a species of helix occurs in all the strata, not merely imbedded, but filled with a hard stone, yet in this island there are six or seven marked divisions in the section, showing different deposits of red earth (fig. 5), similar to that on the surface, not only in composition, but in being deposited in the rude troughs formed by the abraded basset edges of the strata. The rock above *d* is uniform in structure and texture, and thus contains the best quarries; that below it, is generally rubbly and short-grained, varying constantly from a hard limestone to loose sand; below this bed also, numerous caverns (*b*,) have been opened during the progress of the fortifications; and, with but very few exceptions, whenever they are perfect, they contain salt-water, having their bottom below the sea level. In every instance except one (fig. 8. p. 112), the red earth lies almost immediately on the roofs of these hollows, fig. 7. *l*.

Ireland is remarkable for having the finest quarry of building materials in the whole group. The stone of the eastern half consists of fine and coarse particles of comminuted shells or corals, hard subcrystalline limestone, and masses of corals imbedded in compact or granular limestone. The softer varieties prevail from Cockburn's Cut, westward.

Alluvium.

All that can be noticed under this head is the black, rich, tenacious mud of the marshy districts; it has obviously much of a vegetable nature, and makes an excellent garden soil when mixed with the red earth.

By different measurements which I have taken, the Mangrove Swamp and

Salt Marsh A* is on a level with B: as far as I can judge, all the others in the islands are not above the sea level. The water is almost fresh, but in summer, these ponds become stagnant and very offensive.

Encroachments.

Land on Sea.—The harbours and inlets of Bermuda share the same fate as those of all other places, where it is easier for the sea to introduce silt and sand in its first strength, than to withdraw it when the velocity of its waters is reduced by the obstructions of the sand-banks, rocks and reefs forming the confined and labyrinthine passages among coral groups.

Thus at the head of Crow-lane, Bermuda or Main Island, within the memory of the present generation, ships of some burthen used to lie at wharfs, where now scarcely a large boat can repair at all tides. The same has occurred in the narrow channel between Ordnance Island and the Market-wharf at St. George's, but to a far greater extent.

The Flatts Inlet, entrance to Harrington Sound, is perceptibly filling, notwithstanding the benefit it receives from the Sound as a backwater.

Sea on Land.—There is a limit to these encroachments; for although the action of the sea is powerful enough to undermine the ordinary strata, yet when it reaches the hard calcareous rock it can proceed no further; and this stone, which I shall hereafter designate as 'Base rock,' will be found wanting under all the recent landslips; hence, with these exceptions, I know but one instance of marine encroachments. In 1801 Shelly Bay scarcely existed: what is now the mouth, was at that time a row of sand hills; and the road on the north side lay close within. Some free blacks who lived there, being in want of fuel, cut down the plants which kept these sand hills in a solid state. Being no longer duly opposed, the sea quickly broke through, and now retains possession of the ground at least 100 yards in rear of the old road, traces of which are still visible. The Mangrove Swamp between the beach and the present road, was until then a garden.

Sand Encroachments.—Though there are objections to the last being termed a strictly geological fact, yet I have introduced it, and the following details of the sand flood at Elbow Bay, on account of their great utility.

The proprietor of the principal part of the land of this bay, the venerable Captain Lightbourne, remembers an attempt about seventy years ago, when the inhabitants expected an attack from the French and Spaniards, to form a breastwork along the sand-hills, which then, as at Shelly Bay, skirted the coast. In doing so, they cut through the natural protections given by the sea-shrubs and creepers which usually abound in such places. From that day the sand, supported by constant supplies from the sea, has steadily proceeded up the hill to the very summit, a height of about 180 feet. It is, however, surprising to observe the singular state of arrest under which the

* Map, Pl. VI., Fig. 2.

invader stands before the children of the soil. A few straggling cedars, widely scattered in advance of the wood which now bounds the space, have been passed by this sand flood, yet the dazzling, dry, and almost snow-white sand is checked, before the front rank of the trees, in a steep bank, varying from ten to twenty-five feet in height, and so remarkably well defined that scarcely a particle is scattered beyond a distance of twenty yards. As soon as the mass shall have overtopped the woods, I know nothing capable of opposing its progress, as there are no streams at Bermuda to act like the little brook in St. Owen's valley at Jersey*, which has so effectually stopped the march of the Quenodis.

Although this inroad commenced so long ago, yet the principal advance has been since 1807, from which date about 200 yards have been gained on the eastern side. Before I left the colony in March 1833, the sand had reached the northern corner of a cottage belonging to a man called Ned Keel (on Mr. Butterfield's estate); and the top of the bank, eight feet high, was on a level with the eaves of the shed. During the last fourteen years it has progressed, at this point, only about forty yards, in a bed from four to eight feet deep, in consequence of the repulsive action of a thin belt of cedars just below. Very near this spot also, is a small circular group of the same trees, which the sand has passed, and imbedded to the depth of from six to eight feet; but the space within has been so perfectly screened, that the bottom of this little oasis is the natural greensward.

There is another encroachment at Tucker's Town, said to have taken place about sixty years ago; and has crossed the neck between Harrington's Sound and the sea; but beyond this it does not seem inclined to move. The sand has not been stopped, at the eastern extremity of this beach, where the bluffs commence, by their very considerable declivity,—though it has been most effectually at the crest of the slope, by a natural fence of sage bush, growing partly in the soil and partly in the sand; which, as it ascended, seems to have thus rolled on with the seeds of destruction to its progress, in its own bosom.

The same operations appear to have occurred throughout the sand tracts at and near Great Turtle Bay. Whatever scheme may hereafter be executed for the further defence of the south side, it will be well to remember the fate of Captain Lightbourne's property; so that if a military road be formed over such ground, to make it on the turf, and on no account to cut through it.

Hence also, where a stream of water cannot be commanded, plantations of trees, suitable to the soil, will for a long time maintain a very efficient opposition; and though it is to be feared, that eventually they must succumb, where turf and creepers have not established themselves, still, to have effected the preservation of a district for a generation or two, cannot be considered as the attainment of a trifling object.

In Elbow Bay the sand contains, generally on or near the surface, layers, scales, and tubes of calcareous stone, which cannot have been many years in forming, though I have not sufficient data to determine the precise number.

The greatest thickness of the layers is about $1\frac{1}{2}$ inches; and although found on the surface, they are not, I apprehend, produced there, but at a few feet or inches beneath. The sand on the weather side of the little saddles is constantly blowing away, and the edges of the reverse strata, or rather lamina, becoming exposed and undermined, fall down.

An inspection of some of these slabs will prove how perfectly, recent specimens may be con-

* See a paper of mine, published in the late Quarterly Journal of Science for October 1829, on the Geology of Jersey, and its relation to that of the Devonshire and Norman coasts.

tained in stone which has acquired great hardness. On the beach, about 300 yards west of Roselands, the matrix was so firmly attached to slabs of sound, compact, sonorous limestone, as to be in many instances perfectly identified with them. It cost me nearly as much labour to dislodge some of these specimens as I have bestowed on greenstones. An Astrea, like *A. Rotulosa*, *Turbo Pica*, fragments of Ostrea, Spondylus, &c. &c., all contributed with the shelly sand towards the formation of this striking conglomerate.

Other blocks of coral reef may be found, imbedded in the rock on the south side. There is one in particular 300 yards east of Elbow Bay, about ten yards from the water's edge, and four or five feet above it; at some points this block is quite assimilated with the matrix, but at others, stands out in relief, in consequence of its greater durability.

The calcareous tubes are very generally found throughout the islands, apparently aggregated around grass or small roots, as nuclei, which have subsequently decayed. They have almost always an earthy matter running down the axis. Beds, nay strata of these tubular deposits, may be found in various parts, as in the neighbourhood of Tobacco Bay near St. George's, and in the bank a little to the westward of Harris's Bay, where the cliffs commence; though nowhere to such an extent as at Ireland Island, between Bombay and the south-west point, where the stratum is about four feet thick, and corresponds to a similar formation on Skinner's or Tate's Island.

The cliffs to the westward of Elbow Bay are curiously perforated to a great extent by similar tubular holes; but there they are detached from each other, and are generally vertical and much larger.

Organics.

The whole of the Bermudas, and perhaps many of the older rocks, may be called "Organic Formations," as they present but one mass of animal remains, in various stages of comminution and disintegration. From the most compact rock to the very sand of the shore, the materials are universally fragments of shells, corals, &c. &c. Of the former the *Venus Pennsylvanica* is the most abundant, being found in every part of the colony, more especially among the newer aggregates on the coast; and in every state, from the perfect specimen to the smallest particle. A stratum of these, in indifferent preservation, is in the quarry whence the stone for the pier at St. George's ferry was obtained. This bed, however, is of trifling extent compared with an apparently corresponding one in the chain of islets reaching across the mouth of Crow-lane Harbour, beginning near Phyllis' Island, and continuing thence through every point in the line till it reaches Harris's Island: it is about five feet thick and lies about six feet above the water.

In the chain above-mentioned I have obtained excellent specimens of the *Scutella Quinqueforis*, having the pores of the crust filled with crystallized carbonate of lime; like the Echinites occasionally found similarly circumstanced in the European chalk.

The *Turbo Pica* is very abundant, with the nacre and colours; but like the *Venus Pennsylvanica*, it is chiefly met with in sand-pits, and more recent formations, though without the slightest reference to the hardness of the

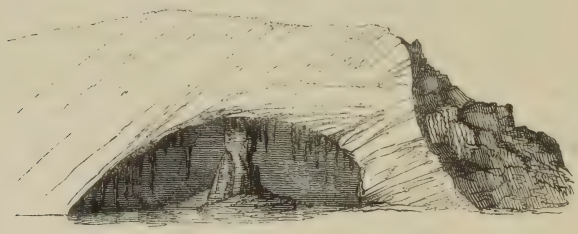
stone containing it. It seemed difficult at first to account for these large shells (*Turbo Pica*) being found on heights, where, from their weight, it was impossible to suppose they had been carried by the wind; but a solution may be found in the habits of the Soldier Crab, which, on more than one occasion, I have seen running about in these shells.

The most interesting organics with which I have met, were in the rock now inclosed by the North Bastion, at Ireland Island.

Whilst cutting the escarp of this work, a large block of reef was discovered in the solid rock, fifteen or twenty feet from the surface, and at about four feet above high water. This specimen contained *Mæandrina areolata*, the common Mytilus of the coast, retaining its black colour, and a pink Millepore very common in the serpuline reefs. This spot, conceiving the truncated strata of Ireland to be restored to their proper form, must have been at the very apex of the saddle, and is perfectly distinct from the loose, soft, and newer sandstones. Above the level of this spot, lie the strata *a a*, fig. 8, which for some hundred yards along the north side, consist chiefly of a hard subcrystalline limestone.

Although this stone is by no means as subcrystalline as the transition, or other old limestones, yet it is sufficiently so to show that the structure can be attained by very new rocks, and by other means than that of heat under pressure. Had heat been in anywise applied to such extent, it is more than probable much of the carbonaceous* matter (one of the constituents of the shelly sand) would have been altogether evolved, and would not have remained, black and mixed amongst the particles of the rock. At all events the colours of the Mytilus and Millepora could not possibly have been retained.

Fig. 8.



In the centre of this rock, fig. 8, was a cavern; and entangled amongst the stalagmitic lining (as well as in that of other caves and crevices), or else lying in heaps in the loose red earth within, we found abundance of a large and delicate Helix. In another instance, upwards of thirty bushels were discovered, without any earth among them: a circumstance easily accounted for by the common habit of these animals to shelter in holes, wherever they can find them.

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* I have paid some attention to the membranous tissues of zoophytes, and find full proof of their existence in many varieties of the Bermuda stone. A careful solution in very dilute muriatic acid, generally gives a minute flocculent precipitate, which the microscope shows to be the mere animal part of the subject.

I have never seen these creatures alive, nor have I ever heard of their having been seen in that state; but still they were found with a smaller Helix deep in the compact rock at *e*, fig. 5. This Helix, which is the common, living snail of the island, I obtained in the hardest stone, and in the loosest sand; sometimes lined with druses of carbonate of lime, sometimes filled with a solid cast, at other times slightly cemented together, and frequently retaining some colour; in which condition they are generally found, as before mentioned, in every part of the colony.

Returning to the cavern at the North Bastion (fig. 8.). In the heap of red earth, which in this instance only had rather an unctuous feel, mixed with the large Helix, were found quantities of birds' bones. From the best accounts, the caves at Ireland were frequented until lately by a sea bird, whose local name, derived from its peculiar cry, is Pim-li-co. In hazy weather, or at night, this sound was always a warning for vessels from the West Indies to put about, and avoid the perilous south-west bar and reefs; but since the establishment of the dockyard at Ireland, these birds have almost left the Bermudas.

Whilst excavating a ditch near the cavern *b* shown in fig. 5, p. 108, a small hole was discovered in a rather hard rock, composed of comminuted fragments, with the interstices not filled up; it was about twenty feet above the sea, thirty yards from it, and fifteen feet from the top of the hill, but without any apparent connection with the surface. In this hole were found an eggshell and many fragments of bones, similar to the preceding, but they were all, as well as the egg, coated with carbonate of lime*.

Ireland is however by no means the exclusive mine for these fossils. Bones, apparently those of birds, have been found in the limestone on the coast of Harrington Sound by Mr. Hill, to whom I am indebted for the information. He obtained specimens fifty feet from the water, twenty feet above it, and four feet under the surface. Three eggs were found close to the bones, and similarly imbedded. Another egg was found in a block of limestone near Hamilton.

A gold knee buckle and a canister shot were dug up in a coarse limestone, whilst excavating the foundations for one part of the North Bastion, across the bottom of the cavern: they were accompanied by *Scutella Quinqueforis*, containing crystallized carbonate of lime as before, and *Agaricia undata*. This rock, a genuine coral rag, is three or four feet thick, and is evidently in a progressive state of consolidation. As it was under water, and as we constantly find stalagmite in the caverns similarly situated, it seems that evaporation, however conducive to the compactness of strata, and the depositing lime once held in solution, is by no means a necessary requisite.

Turtle bones were also procured from the North Bastion coral rag, and from the sands at Elbow Bay. The turtles seem, like the poor bird before mentioned, to have been buried while depositing its eggs, as the two skeletons when first discovered were entire and undisturbed. Their dimensions were nine feet in length, and seven in breadth, as I was informed by an eye-witness.

These bones, as well as those of birds from the North Bastion, Harrington Sound, and the ditch near *b*, fig. 5, all adhere strongly to the tongue; hence no further reliance can be placed on this circumstance as a criterion of age. Nor can crystallization or compactness be considered unequivocal testimony, in arriving at conclusions respecting the age of a rock.

In the North Bastion, in the interior crevices of the coral rock, were many fine specimens of Cypræa and Bulla, but with abraded surfaces.

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* It is the known habit of many sea birds, particularly the tropic bird, or 'Boatswain,' so numerous at Bermuda, to make their nests in hollows of the cliffs; and it would seem as if the animal had been immured during the period of incubation, by some fresh deposit of sand which had afterwards hardened into the walls of its prison house.

The last individual Animal Organic which I shall mention, is a Strombus which I chiselled out at Long-bird Island, and had the cavities in the substance of the shell filled with crystallized carbonate of lime. I may terminate this list comprehensively by saying, that almost every shell now known in the surrounding sea, may be found in the rock quite perfect, except with regard to colour, especially among the newer beds on the sea coast.

Chalk.—It may be considered rather a bold step to place this mineral under the head of 'Organics,' but from all that I have seen during different examinations of decomposing zoophytes and shells, from the least calcareous to the large and massive Mæandrina and Astrea, not only whilst breaking or cutting them with my own hands, but as obtained from the extensive excavations made by the dockyard diving-bells for the foundations of the wharfs, and from the soil torn up by large mooring anchors, I have no more hesitation in attributing the existence of the Bermuda chalk to such a source, than I have for asserting that the obvious material of the Bermuda stone is derived from the same origin; with, however, this difference, that in the latter instance the fragments are the result of mechanical subdivision; while in the former, the elementary particles are due to the decay, by long submersion, of the membranous tissue*, which, pervading their whole structure, releases the constituent calcareous matter dispersed through the texture, when it is ruined by decomposition. These animals, and the many marine plants, consisting chiefly of lime, produce this chalk, just as terrestrial animals and vegetables give carbon to soil when they decay. I no more pretend to argue that the European chalk was thus produced, than that the caverns of all the various limestones were formed by means similar to those which excavated the caves at Bermuda (see page 119); or that the coral rag of the oolites is related to that of the North Bastion; but certainly the external and the chemical peculiarities are as much the same as their common character of being marine deposits.

This chalk, as found in the harbour bottom, is much mixed with shell-sand, corals of many sorts, shells in a perfect state, and gigantic masses of equally perfect Astrea and Mæandrina, as well as in every stage of decay, leaving no doubt of their having lived and perished where they are found. The aspect of this chalk when fresh, is precisely that of crude mortar. A variety, which may be termed stalactitic, was found in some of the newly opened caves, and resembled curds in consistency†. In some cases it occurs in small shapeless deposits among the regular strata, or lining the crevices and insides of caverns. This variety, when dry, consists of very fine white powder, which yields to the least pressure and soils the fingers.

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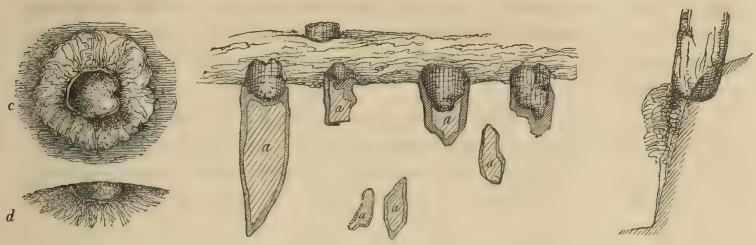
* When a *fresh* specimen of any sort of coral is carefully submitted to very diluted muriatic acid, the membranous tissue may be obtained as satisfactorily as from a bone.

† The same substance is to be found on the lower surface of the crust covering the bottom of Chudleigh rock caverns.

The surface of the calcareous sandstones, is, in some places, coated by compact stalagmite, and I believe a strong resemblance, if not identity, will be found between its nature and the hard chalk near the basaltic districts of Antrim, the solidifying of which has been attributed to fire. This inference may be true; but here is a clear fact, that such limestone can be otherwise produced. Not that the conclusions from Sir J. Hall's most interesting experiments are the less valid, countenanced as they are by the results of the action of Trap and Whin on the immediately contiguous strata. Such a mode of consolidation, however, is not perhaps so likely to occur on an extended scale, or to produce such regular strata, as that which has formed the Bermuda stone. It is, moreover, an additional means of arriving at certainty, to allow *every* known force its fair consideration.

Fig. 10. Fig. 9.



Vegetable Organics.—These are doubtful. Fig. 9 is however a sketch and section of certain rudely-shaped cylindrical blocks which are to be found on every part of the surface of Bermuda, though I never heard of their being discovered below it. They are very frequently arranged in groups of from twenty to fifty, as if they had once been the roots of as many trees. Fig. 10, *c*, *d*, are plan and section of the recent Palmetto root, which has, in common with the subject under consideration, a very marked socket, or deep cup*. When this tree dies, it generally falls out of the cup, of which excellent examples may be seen at low water in Shelly Bay, north of Harrington Sound, Bermuda. It is the general surmise that these curious cylinders (fig. 8) are the remains of the Palmetto. I think it very likely that they belong to a member of the family of Palms; though I have my doubts as to the Palmetto being the individual, as the internal surface of its root socket is entirely composed of

* Sometimes only casts of these roots are left as pits in the rock; but in the compacter limestones, I have more than once met with cylindrical excavations, evidently the work of water. They vary from two to three feet in diameter, and may be about eight or twelve inches deep. These are mentioned merely from their singular resemblance to the 'Rock Basons,' on the crags of Dartmoor, supposed to be Druidical. That which I have more particularly in mind is on the apex of Heytor. The flat bottom of the latter showing its broad streaks of felspar, had evidently a different origin from the equally flat ones of the Bermuda pits, which seem to be a natural deposit and mixture of sea salt and sand.

the ends of the nearly straight and tubular roots, about one-fifth of an inch in diameter, which diverge into the ground as so many radii. Now in the supposed organics, in the inside of the cup, although smooth, I never could detect these ends of the radicles; and there is too much irregularity to allow me to join in the received opinion without hesitation; though nothing like any other description of palm relics has been yet discovered.

Reefs.

The notices relative to these structures, which I at first intended for this paper, have so exceeded it in bulk, that they are reserved for a separate essay. I merely remark that there are two distinct kinds; those formed by Serpula, and those by Zoophytes of all descriptions, which construct calcareous skeletons.

Figs. 11, 12, and 13, exhibit such plans, sections, and views as will suffice to illustrate their leading peculiarities, especially one that is common to both varieties, that of forming a belt round any obstacle which offers a rallying point; whether such centre be the head of a rock, or the base of a mountain.

Fig. 11. Plan of a Coral Reef forming around a sandbank.

Fig. 12. Section of a small isolated Coral Reef.

Fig. 13. Serpuline Reef and Section, near Elbow Bay.

Diluvial Agency.

External Evidences.—Fig. 2, Plate VI. illustrates the true forms of the ground taken at points in the islands without any especial selection. The lines are surveys of horizontal contours, traced by a spirit level, at given heights. An eye accustomed to such topographical considerations, will, I think, recognise a similarity to the results which in other parts of the world have been referred to the sweeping action of a huge body of water.

I cannot but suppose that such singular lines of islets, as those terminating Long-bird island, those in Crow-lane Harbour, the 'Stags,' near Crawl Point, &c., are most naturally accounted for by the exertion of such a force; as the strata in these little spots are nearly always horizontal, and evidently frusta of a more extensive formation.

It has just been stated, that reefs generally collect close, and parallel to any shore as a nucleus. Throughout the whole extent of the south side of the group, there is exactly such a general conformity to the shore in the Serpuline reefs, which, nevertheless, vary in their distance from it, between fifty and five hundred yards. Its contour-like resemblance (Map, Plate VI.) to a former coast line is very striking, especially when the numerous coincidences are duly considered between the present positions of its fragments, and those of the more or less truncated hills along the sea side; at the original foot of which they would generally lie, were the slopes of the ground restored.

Such circumstances can however yield only probable evidence. To convert them into positive testimony we should require that points of hard persistent rock should appear through this reef at such irregular distances as would be suggested by the variable density of the Bermuda stone; and we might likewise expect that, occasionally, the summits of these peaks should exhibit a stratified appearance.

We have abundance of such witnesses in what are called 'Boilers,' 'Breakers,' &c., or rock heads, which have served as points of aggregation to the reefs around them. Such are the Boilers on the continuation of the line of the point, at the west end of Great Turtle Bay; those in the centre of Common Landing Bay; the long and dangerous chain of about thirty sunken rocks, between the Bear Boiler and the South-West Breaker; the 'Stags,' between Ireland island and Spanish Point, &c. &c. From accounts received, I have reason to suppose that such are to be found all round the North Reef; but at one place I am certain of it, the 'North Rock,' or as the old French maps used to call it, "La petite Bermuda;" and it is to be observed that the

highest pinnacle bears the ultimatum of the desired evidence of 'Diluvial Agency,' a stratified summit, as pointed out to me by the keener eye of my late brother officer, Lieut. Browne, R.E.

This monument to departed strata, stands in a Serpuline reef, which is as usual tabular, and appears above low water. The largest rock is about sixteen feet high; and like all those which have withstood the onset of the Atlantic, is composed of "base rock."

Internal Evidence.—Ireland is the only place, as far as I am aware of, which has supplied such arguments; the deposits of red earth in fig. 5, contain stones that would have been too heavy for the wind to have moved without utterly dispersing every grain of the soil containing them. From the number of these deposits, we are warranted to conclude, that five or six such catastrophes have befallen these islands; though the organics establish clearly enough, that as delicate land shells, they and the strata in which they are imbedded could never have been produced under water; and if a rock in the heart of an island, and at its lowest point, presents animal remains possessing even colour and membranous tissue, with a considerable degree of perfection; the superincumbent masses cannot boast of any great claims to antiquity; hence the expression 'Diluvial Agency,' as the heading of this section must not be restricted to the Noachian deluge, but to the repetition of several probably subsequent, local ones, and the results of distant volcanic action.

Caverns and Pinnacles.

The caverns are numerous, and many of them very beautiful. The largest, and, geologically speaking, the most instructive, is Basset's, near Somerset-bridge. It is said to extend for more than a mile; but the first few hundred yards of toilsome progress usually satisfies the curiosity of the majority of its visitors. It seems to be comparatively recent, from the fresh state of its surfaces, and the small quantity of stalactite observable; this absence of incrustation, however, renders the origin of this cavern very palpable; namely, the undermining of the substrata by the sea, the waters of which lie in pools at the bottom. Hence we may consider such caverns as hollows produced by internal landslips; from the most normal of which, to the simplest niche, there is every intermediate point of transition. The north side of the Main island is to a remarkable degree indented with these recesses; and when they occur in more sheltered places, are sure to be rich fields for the naturalist.

Fig. 14.

Fig. 8 (p. 112) exhibiting the section of the cavern which once existed under the North Bastion, and Fig. 14 a section of the ground and its caves near the Magazine Pond at Ireland, are I apprehend sufficient to explain my views respecting the origin of these phenomena, as far as Bermuda is concerned.

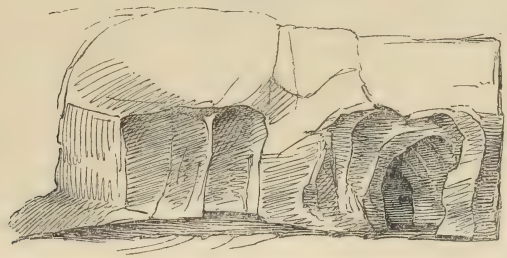
The caves at Walsingham, near the Ferry, are well worth examination, but in point of speculative interest, they are inferior to the many and very singular hollows near them, on the neck of land separating Harrington Sound from Castle Harbour; respecting which, all that I can venture to surmise from their sections, their steep and occasionally overhanging sides coated with stalagmite, is, that they are the remains of former caverns, laid bare by diluvial action. Vertical sections of caves are common enough in the cliffs, Fig. 5, *c*; and oblique sections (such as that so well known, close to the Ferry, between St. George's and Hamilton) are not unfrequent on hill sides.

Tucker's Island cavern was a perfect bijou; with one splendid exception it has hitherto stood unrivalled amongst the caves of Bermuda.

This little cavern shown in fig. 5, *b*, had a length of eighty feet, a breadth of about fifty, a height above the little lake within of at most fifteen, and a depth below its surface scarcely exceeding fourteen. The stalactites were remarkably clear and beautiful, varying from the massive pendent of six or seven feet in length, to the slender incipient fragile tube, which crumbled at the slightest touch. It was a scene not to be readily forgotten, when we launched a little boat into the miner's first and narrow opening, through which the sun shone strongly, and reflecting its light from the face of the water upwards and with power to the sparry fretted ceiling of the vault, illuminated it in a way which can only be appreciated by those who have been eye witnesses of such effects. This cave was shortly afterwards destroyed, as interfering with the safety of the works.

The irregular density of the rock is exhibited on all scales, from minute flaws and patches to large masses of dry sand; which more than once occurred during the progress of our excavations, in the heart of otherwise hard, sound rock. Fig. 15 is a sketch of one of these hollows; and whatever may be the scale of operation, it is just such a form as would have been left had the sea extracted its contents.

Fig. 15.



To the unequal distribution of that carbonate of lime in solution, which forms ordinary rock on the upper parts of a section; or druses and breccias, as it filters through the strata of red earth to the lower beds or to the caverns where it crystallizes as stalagmite and stalactite, I attribute, not only the caverns and sandflaws, but the pinnacled rocks almost equally common in the islands. The most remarkable groups are at Tobacco Bay, St. George's Island (fig. 16), and at the North rock. I cannot but consider these as merely blocks, sufficiently impregnated with the dissolved carbonate of lime to have resisted the attacks of the waters, with the same success as the 'Base rock.'

Fig. 16.

I apprehend that such caverns as those described in the preceding pages, are rarely found in any but calcareous rocks. The Grotto of Antiparos; the caves of Torquay, Chudleigh, Plymouth, and Kirkby, as famous for their organic remains, as those of Gaylenreuth and others, in Germany; the various caverns in Derbyshire; Peter Frazer's Bear Den, near Picton, in Nova Scotia; the different subterraneous courses of certain rivers in England, &c. &c.; are all found in limestones of various formations. It is almost trite to quote such instances to the general geologist; but I have thus reassembled them, to show how well the series is terminated by the corresponding examples, which have supplied the materials of this section.

Water.

Fresh water may be had in nearly all parts of the islands, provided the bottom of the well is not sunk under the level of low tide. Generally speaking, it is deemed prudent to be contented with twelve or eighteen inches of water, rather than incur the risk of rendering the well brackish; since, from the porous nature of the rock, the salt water always filtrates through.

At the naval wells below Mr. Langton's, where large quantities of water are required for shipping, it is only taken between the half flood and half ebb, to avoid the brackish quality of water drawn at improper seasons; for all the wells, on the sea coast, are affected by the tide; and more or less so those at a distance from it.

Building Materials.

The Bermuda rock is much whiter than the 'Bath stone.' Blocks of any ordinary size and strength can be obtained. The softer kinds, weighing at an average about ninety-five pounds per cubic foot, with a cohesive strength equal to only a quarter that of brick, are quite strong enough for house walls, where no great skill is required from the stone-mason. The houses are in general roofed with thin slabs of this material, which admit rain unless secured by proper washes.

The harder sorts, like those of which the eastern half of Ireland Island is composed, vary in specific gravity from 1600 to 2560. In raising these, powder must be employed; and the usual tools for hard stone, in their conversion into ashler. In large masses, such as escarps, wharf walls, &c., it generally answers tolerably well; but it scarcely deserves a very high reputation, from the cracks which the unequal composition of the stone occasions, when under very heavy pressure.

It is too pure to afford a good lime for external purposes, as it takes a long time to harden in thick walls. Equally good lime is manufactured from all descriptions of stone found in the island, regulating the choice by such localities as determine the economy of the burning process.

The Bahamas.

Judging by hand specimens, from such reports as I have been able to collect, from their form as given by the best maps, and their position with reference to the gulf of Mexico, I think it highly probable, that the Bahamas were produced by the same causes as those to which the Bermudas owe their existence.

I have been told on respectable authority, that the red earth is to be found on the coasts of Florida. I have also seen specimens of Menacchinite from the shores of Virginia.

Concluding Remarks.

Amongst the different speculations on the origin of coral groups, none are more common than such as would effect the whole by plutonic action; but I can see no proof that the islands, though once formed beneath the surface of the sea, were suddenly and subsequently elevated. The peculiar arrangements of the strata, both in the mass and detail, and the constant occurrence of the Helix, appear to be conclusive against the above theory; and if dislocations of strata do occur, in only one instance (fig. 13, p. 118) are they to be met with to an extent like those, which I have seen in the chalk near Dover, and at Alum Bay, and due to undermining of the strata.

In most notices on the Sunderbunds, it is stated, that islands are rapidly formed around any nucleus, such as the trunk of a tree in the bottom of the river, &c., which, reducing the velocity of the current, affords it the op-

portunity of depositing the sand; and this procedure must necessarily be of universal occurrence under similar circumstances.

Once thrown down, unless carried off by a more powerful action than the original one, every fresh layer of sand not only increases the obstacle, but likewise the tendency to arrest the passing materials, until such time as a limit is attained by the increased, and consequently destructive velocity of the current in the thus narrowed channel.

Assuming then any such initiative, as the head of a rock at the bottom of a sea in which enormous districts of zoophytes, &c., abound, as between 32° or 34° on each side of the equator, and from which dead portions to a considerable amount are incessantly torn off, and moved on with the waters until stopped by the rock, there will then follow the continued operation of the preceding law, of which this is the commencement.

Zoophytes and other marine animals, of which the germs are passing on with other matters, attach themselves, as my own observations enable me to assert, indifferently to the first base they can find; and by their growth, reproduction, and death, add to the stability and bulk of the colony. In this manner, I conceive* submarine mountains are constructed, and around their summits, the coral reefs.

If the tides have their usual action and alternate direction, then the necessary form assumed by such a bank, will be like that of the average of sand banks and coral groups, elongate, and more or less ovate.

Such germs as are dispersed in the water, on touching the bank, will on the whole collect in greater quantities on the declivities of the edges than on the plateau of the upper surface, over which they are far more likely to float away. Most zoophytes affect a vertical growth, and in this attitude have a tendency to add to the accumulations of the exterior fence, to the prejudice of the space circumscribed.

Hence, I would surmise, is their generally annular form; and as to their somewhat uniformly level upper edges, that is of course regulated by the surface of the tides, above which the animals cannot for any length of time exist.

The Bahamas lie in the bight of the gulf-stream, and the Bermudas on its outskirts; whether this is, or is not, the immediate parent of these groups, if we admit the above premises, then once above water, the wind is sufficient to complete districts of indefinite extent; and far larger than those which have formed the subject of this Memoir.

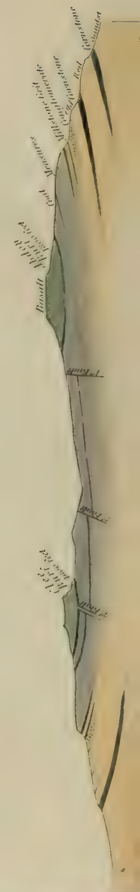
Although the stone has been described as forming rapidly at Elbow Bay, I

* In some places the reefs interfered with the works; and when destroyed in consequence, I never saw sufficient reason to induce me to alter my views as above stated.

can scarcely imagine the probable depth to which such accumulations are likely to be consolidated. As a tolerably general rule, the upper strata are less compact throughout the Islands than the lower ones; but there is a contradiction to this, not only in the large and deep sound cliff from which our works at Ireland are supplied, where the bottom is as soft as the top, but in the still more remarkable instances afforded by the beds of sand, mentioned at pages 106 and 107, as lying just above high water along much of the south sides of St. George's, and of the Main island. These sand beds lie under cliffs of good rock, sometimes fifty feet high. Why has not the rain water deposited the lime which it cannot but have dissolved in its passage amongst these beds?

I had a tube, two inches square inside, and six feet long, filled with sand, suspended vertically from a shelf. For two years water was kept dripping on the upper end, with no greater interruptions than those which might have occurred from an occasional want of rain; but on opening the tube at the end of that period there was not the slightest appearance of cohesion amongst the particles of sand. Want of opportunity for the water to evaporate through the sides might account for this; but such heavy exceptions to an extensively applied general rule, like that regulating the consolidation of the Bermuda rock, are very embarrassing.

Section on the Line AB.

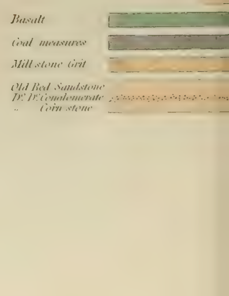


PLAN & SECTION of the

BROWN CLEE HILL,

SALOP.

Scale 2 Inches to one Mile.



Section on the Line CD.

VI.—*Notes on the Geology of the Brown Clee Hill, in the County of Salop.*

By ROMLEY WRIGHT, Esq.

Employed on the Ordnance Trigonometrical Survey of England.

[Read Dec. 18, 1833.]

THE old red sandstone which forms the base of the Brown Clee Hill*, generally dips from 5° to 10° to the east and south-east. Its lowest beds are remarkably soft and clayey; but through a large portion of the counties of Hereford and Salop, it almost invariably contains one or two beds of limestone, provincially called cornstone, and much used for agricultural purposes.

The old red sandstone, as it rises towards the Brown Clee Hill, instead of continuing to dip towards the south-east, gradually assumes a basin-like form; inclining on all sides towards the centre, at an angle of about seven degrees.

A bed of cornstone, about twelve feet thick, ranges almost entirely around the hill; and a second bed, also much quarried, occurs above it.

From the circumstance of these two beds reposing in the form of a basin; and from their proximity to the superincumbent coal deposit, they appear to have been considered as representatives of the mountain limestone: but 150 feet of the old red sandstone lies between these cornstones and the coal measures, and passes on the western side of the hill into a regular conglomerate.

Immediately upon this conglomerate, the coal formation reposes; its greatest thickness being about 150 feet; and the dip of the beds conforms to that of the subjacent strata, or towards the centre, at angles varying from 3° to 5°. The outburst of its lowest bed, locally termed the "Bottom Rock," is marked by a soft white clay, which freely throws out springs of water.

This "Bottom Rock" has but little quartz, and in grain resembles whitish oolite.

Coal has been discovered, to the amount of six feet in thickness, distributed in three different veins, namely,

The Three-quarters Vein . . . 1 foot 7 inches.
The Batty Vein . . . . . 2 feet 6 inches.
And the Bottom Vein . . . . . 2 feet.

When worked it is chiefly by means of a windlass; but the beds are neg-

* Plate VII.

lected in consequence of the superior quality of the coal which is found three or four miles distant, in the Titterstone Clee.

There are three separate faults, ranging nearly parallel to each other in a north-east direction*. The first, which is but a few inches in width, throws up the coal veins about three feet on its south-eastern side; the second throws them up about five feet; and the third, which ranges near the centre of the superincumbent mass of basalt, called the Clee Burf, is about thirteen yards in horizontal thickness, and throws up the measures nearly nine yards.

The "Wall," as this last fault, or the basalt which accompanies it, is termed by the miners, is so hard as to require to be blasted, no tools which they possess being able to work it; but the coal in immediate contact with the basalt, is represented as not being in the least charred.

It may be followed on the surface for about 400 yards, and in the prolongation of this line, the measures are found in abrupt and unconformable contact with the old red sandstone; the lower beds of which also lose their continuity, as may be observed above Pickleton Grange.

The coal field of the Brown Clee Hill, comprises nearly two square miles, and, owing to an inosculation near the middle of the hill, its outline much resembles a figure of 8 (see Plate VII).

Within its area are two isolated caps of basalt, forming the highest points of the hill, namely, the Abdon Burf, exceeding 1800 feet above the level of the sea; and the Clee Burf, which is about 200 feet lower. The basalt of Abdon Burf appears to be about 140 feet thick, but it has very extensively fallen down, and now appears only in the form of large blocks of stone.

To the eye the basalt precisely agrees with that of Rowley Regis, near Dudley; and is much finer grained than the basalt at Earls Shilton in Leicestershire. From the large fault in the coal measures, specimens of the rock were obtained, similar to the overlying mass of basalt. After the most careful and repeated examinations, no traces of a columnar arrangement could be perceived in the basalt of the Brown Clee Hill. From the almost inaccessible nature of their situation, each of these two hills was formerly occupied as a fortified post, in the same manner as the Titterstone Clee. At Bouldon, about two miles distant, there was formerly an iron furnace, and it is generally believed that the ore was obtained from the Brown Clee Hill. Immense heaps of refuse are yet seen, from which the metal has been but very partially extracted.

It is certain that iron ore is associated with this coal deposit; but its site is not sufficiently known to admit of being introduced into the accompanying plan; for the same reason I have omitted to mark the outburst of the beds of coal.

* Plate VII. Map and Section E. F.

VII.—*Observations on the Geological Structure of the Neighbourhood of Reading.*

By J. ROFE, Jun., Esq.

Communicated by Robert Hunter, Esq., F.G.S.

[Read Feb. 26, 1834.]

I HAVE the honour of presenting to the Geological Society a few specimens illustrative of the geology of the immediate neighbourhood of Reading; and I may, perhaps, be permitted to accompany them with a short account of the beds in which they were found.

The substratum of the neighbourhood of Reading is the upper chalk, abounding in fossils and flints, many of the latter containing sponges or other organic remains, and very many having cavities lined with crystals of quartz of various colours, or with mammillated chalcedony. The chalk on the north-west side of the town, rises abruptly a short distance from the Thames, forming a range of hills; but on the north-east more gradually, and the hills are farther from the river. The high land which, in Reading, separates the Thames and Kennet, rises suddenly from the Holy-brook (a tributary of the Kennet), but falls gradually towards the Thames from the Basingstoke Road to Caversham Warren. The highest part of this ridge is covered by gravel, under which are numerous beds of sand and clay, belonging to the plastic clay formation. In the Thames valley the chalk is principally covered with the gravel over which that river flows. To the south of the town is also a range of high land, bounding the Thames and Kennet valleys; and, like the ridge between the two rivers, belongs to the plastic clay; while on the western side, in the Kennet valley, several brick-fields are now worked through all the strata of that formation to the chalk; and it was in these beds that most of the specimens were found.

In the Katesgrove field, wrought for considerably more than a century, the clay for bricks and tiles is procured from the side of the hill above the general level of the field; but the chalk, used for lime, is obtained from pits sunk beneath it, though never to a depth exceeding fifteen or sixteen feet, as the water prevents deeper excavations. The upper part of the chalk, for about a foot, is in a very singular state. It can scarcely be called chalk-rubble, but

resembles wood which had been penetrated by the teredo, and the tubular cavities afterwards filled with sand. Covering this is the bed of oyster-shells, twenty-seven inches thick, but divided into two parts. In the lower, which is thirteen inches thick, the oysters are imbedded in a brown clay, and are much larger than in the upper, but are more difficult to procure perfect and to preserve, as they rapidly fall to pieces when taken from the bed. In the upper, which is fourteen inches thick, the shells are found in a bed of sand, containing minute green particles, and occasionally small green nodules and flints, some of which are rolled and some angular. In both beds the shells are accompanied with a considerable quantity of fishes' teeth.

Resting on the oyster-shell bed is another of clay, nineteen inches thick, parted by small seams of crystals of selenite; and on this are five feet of quartzose sand, near the upper part of which is a bed of ochreous nodules, from two to three inches thick, which yield an excellent pigment. The strata above this, as far as I can observe, correspond with the statement in Dr. Buckland's Memoir*, excepting that about six feet from the surface of the hill, is a thin bed of shells not noticed in that paper, nor in a passage in the Outlines of Messrs. Conybeare and W. Phillips, (p. 42.) when speaking of this place; or at page 39, where it is said, "There is not the smallest trace of animal or vegetable remains in any of the strata of this formation at Reading in Berkshire, except in the green sand†." In this field, where the bed is so near the surface, it is considerably decomposed and may easily escape notice; but in other places in the neighbourhood, the matrix in which the shells are imbedded is sufficiently hard to take a tolerable polish.

The same beds have been worked through to the chalk, at spots on the other side of the Kennet, and nearly in a line with the Katesgrove field. They contain the sand with green particles and rolled and angular flints covering the chalk, as at Katesgrove, and occasionally oyster-shells and teeth. In making the new road into the town, on the eastern side, over the corporation property, the upper part of the chalk has been exposed and is covered with sand and rolled pebbles, but there are very few of the green particles, and neither teeth nor shells. In this spot the chalk rises very near the surface, and the sand with the pebble bed is very irregular in its thickness, and is covered with the vegetable earth; but in the upper part of a field on the side of the Oakingham road, immediately under the soil, are thick beds of gravel, containing chalk flints, some of them very little rolled, and abundance

* Geological Transactions, 1st Series, vol. iv. p. 278.

† In the section presented in July 1837, the bed was twelve feet below the surface, and about ten inches thick.

of organic remains, principally Echini and Terebratulæ in flint. In the pit on the Oakingham road bones and teeth of the elephant have been found.

To return to the thin bed of shells near the surface at Katesgrove. I cannot discover that it has been found on the north-western side of the town; and it probably crops out at Katesgrove. In Clackman's field, about a quarter of a mile south-east from that pit, in sinking a well the bed was found in a very perfect state about four inches thick, and about thirty feet below the surface; and the shells, though in a very brittle chalky state, were firmly concreted by sand. The best of the specimens are deposited in the Museum of the Reading Philosophical Institution. In these specimens, some of the shells are lined with crystals of iron pyrites and some with crystallized carbonate of lime. This stratum has also been found at several places south of Reading; and at Woodley Lodge, the residence of James White, Esq., about three miles east of the town, the thickness of the bed is about an inch. It was found about forty feet deep, in sinking a well, and immediately under it a supply of indifferent water was obtained.

It is also recorded "that in an unsuccessful attempt to procure coal at Hose Hill" (in the parish of Burghfield, and on the south bank of the Kennet Valley, about four miles and a half south-west of Reading) "a few years ago, a bed of cockle shells, firmly concreted with sand, was discovered about twelve feet below the surface*." This, there can be little doubt, is the same bed as that found at Katesgrove and at Woodley.

Before I conclude I may be allowed to notice another fact connected with Reading, which has been verified by repeated observations and is well known by the well-sinkers. All the wells in the town (excepting those supplied by soakage or land-springs, which are mostly of bad quality), whether

* Since the foregoing account was written, I have been favoured with a letter from Mr. Wheble, of which the following is the substance:—

The blue clay prevailed for about forty feet, when the concrete of shells and clay appeared. On breaking through this mass, water was found in a small stream. The men then continued to sink through a clay streaked blue, red, and white, to the depth of ninety-five feet from the surface. Boring was then commenced and continued about thirty-five feet deeper, always through the second sort of clay, but with more of sandy particles occasionally, without meeting with any further supply of water than the one above mentioned. In the first forty feet many oysters, &c. were found, not concreted, but disseminated in the clay. One large rounded flint with several oyster-shells firmly attached was brought up.

In the course of the sinking, the air in the well was very sulphureous and disagreeable to the workmen, and for a considerable period the water was powerfully sulphureous and chalybeate. The supply of water seems to have increased of late years, but it never rises above the level which it oiginally attaind.

north or south of the Kennet, even those within thirty yards of its banks, are regulated by the Thames, rising and falling with the river, and not being at all affected by the Kennet floods. This may be accounted for by the Kennet flowing through a bed of tenacious clay, whereas the Thames flows through gravel immediately over the chalk, into which all the wells (except soakage wells) are sunk from ten to twenty feet. The depth of the wells from the surface varies of course according to the situation, some being from ninety to a hundred feet deep, others not more than fifteen to twenty.

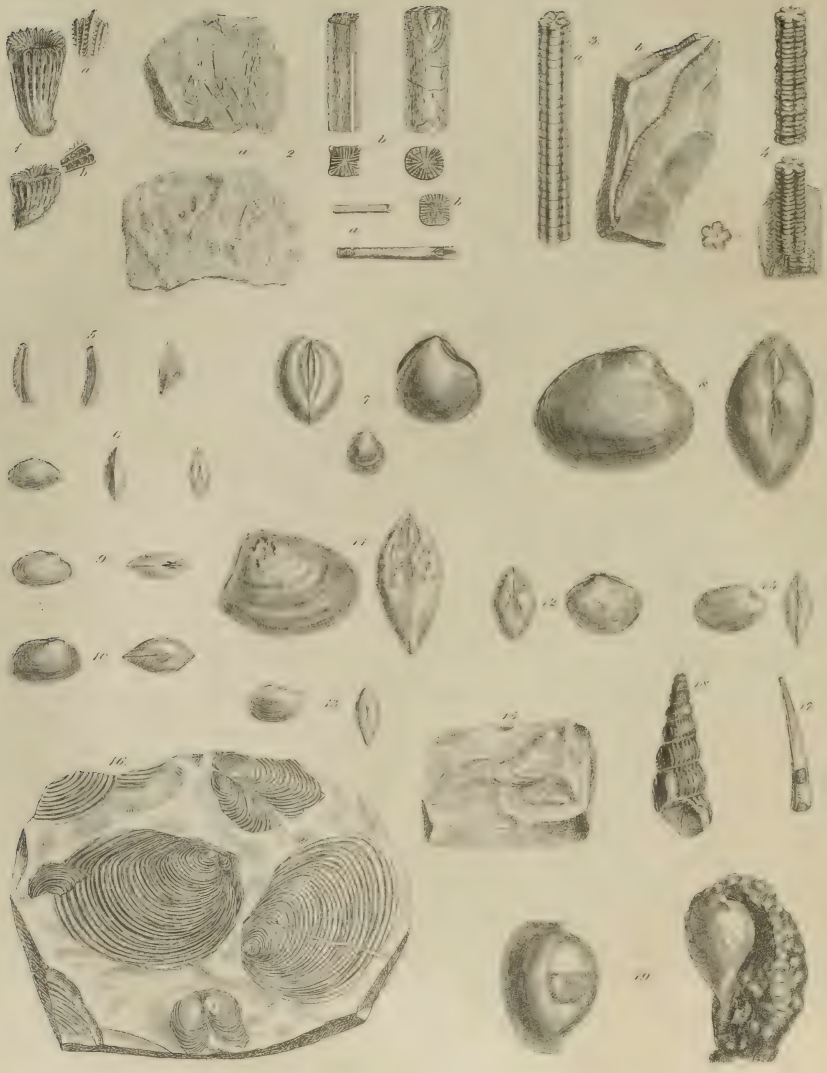
The following is a list of the shells alluded to by Mr. Rofe; and it appears that the upper bed contains the fossils of the Bognor Rock.

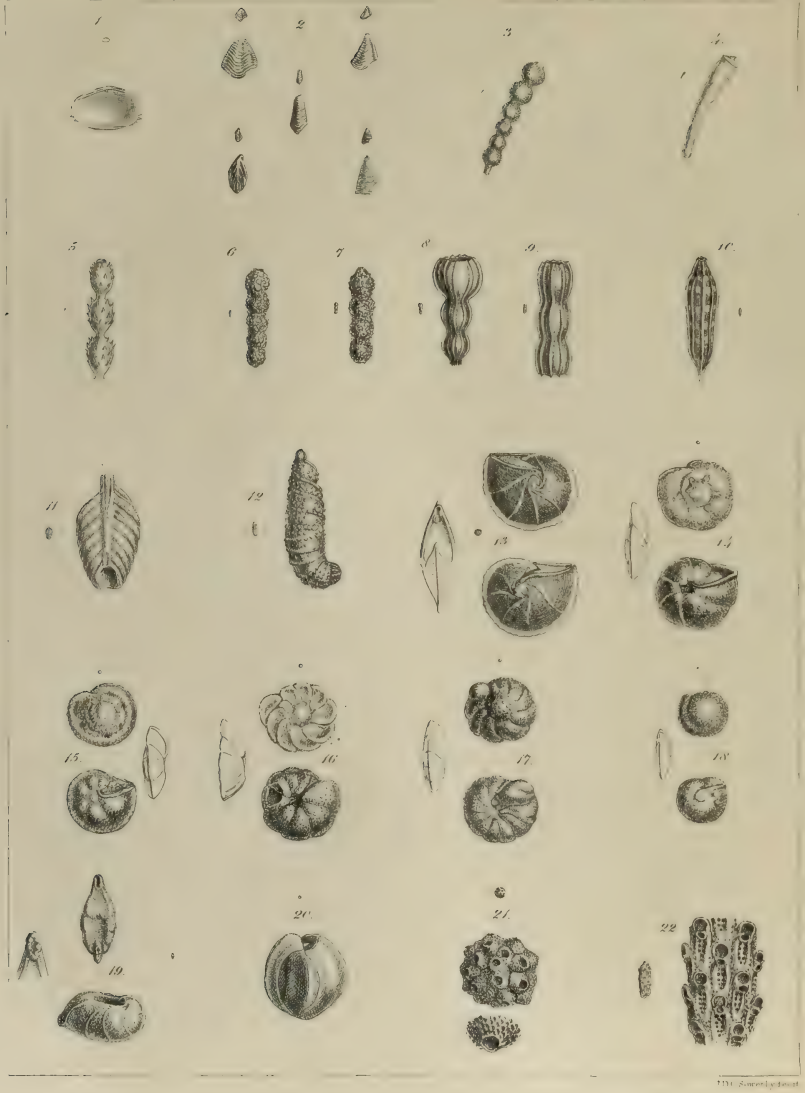
The Upper Bed.

Cytherea incrassata	Min. Con.	Tab. 155. f. 1, 2.	also Bognor.
Pectunculus brevirostris	———	Tab. 472. f. 1.	Ibid.
Modiola elegans.....	———	Tab. 9.	Ibid.
Dentalium planum.....	———	Tab. 79. f. 1.	Ibid.
Ampullaria sigaretina	———	Tab. 284. low. fig.	Ibid.

Katesgrove Oyster-bed.

Ostrea Bellovacina.....	Min. Con.	Tab. 388, f. 1, 2.
—— pulcher	———	Tab. 279.
—— tener?.....	———	Tab. 252. f. 2.

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VIII.—*Observations on a Well dug on the South Side of Hampstead Heath.*

By NATHANIEL THOMAS WETHERELL, Esq., F.G.S.

[Read June 4, 1834.]

A WELL dug at Lower Heath, Hampstead, in 1833, yielded a considerable number of fossils, and in consequence of the London clay having been cut entirely through, and the plastic clay to some depth, it became an object of interest to the geologist.

It is well known that a great part of the heath is covered with sand, which has been described as belonging to the upper marine formation*. At the southern part, however, the sand gradually disappears, and the clay is met with on the surface, and it is at this part that the well was made.

The following is a section of the well.

London Clay	285 feet.
Rock	5
Plastic Clay	40
	330 feet.

The London clay for the first thirty feet, was of a loose texture and reddish brown colour, and contained a good deal of decomposing pyrites and selenite. From 30 feet to 200 feet it varied in colour from blue to dark brown, and contained many septaria. The lower part was as usual very sandy. At 260 feet there were a few fruits and seeds, the former being of the same description as fruits found at Sheppy, and the latter being similar to the seeds obtained at the Highgate Archway. I have a cylindrical piece of pyrites, radiating from the centre, very like that which occurs in the chalk. I mention this circumstance, because the pyrites I had hitherto met with in the London clay were irregular nodules, or flat masses, without any radiation internally. It was found 265 feet from the surface. Between the last-mentioned depth and 285 feet, the bottom of the formation, the clay abounded with vegetable remains in a compressed and decomposing state. The fossil copal, or Highgate resin, I believe was not met with.

* Outlines of the Geology of England and Wales, p. 14, 1822.

Between the London and plastic clays a hard rock, five feet thick, was bored through. It abounded with green, siliceous particles; and contained numerous shells, disposed in layers, but the greater part were in a very chalky, decomposing state.

A list of the organic remains obtained in the London clay, is given at the end of this paper; and on perusal it will be found to contain many fossils which have been met with in distant localities of the same formation, as Sheppy, Bognor, and Barton. I mention this as an important fact, but by no means as a new discovery, since Mr. Parkinson states in a most able paper on the Strata and Fossil Remains near London*, that at Kew and at Highgate Hill, fossils had been found of the same description as those of Sheppy and Hampshire.

In the Hampstead Well were obtained some interesting remains of the class Radiaria. The portions of Asterias in my possession, consist of a considerable number of ossiculæ. The largest, being granulated, probably belonged to the sides of the animal; and some of the smaller, without granulations, to the middle or inner part. The ossiculæ were irregularly distributed on the surface, and within a piece of clay, but by immersing the mass in water, I was enabled to save the greater part.

Of the genus Pentacrinites, I have remains of two species; one is evidently described by Miller in his Crinoidea, as having been found by the late Mr. James Sowerby, at White Conduit House, Islington, &c., and is thus spoken of:

"These columns much resemble in size and shape those of *Pentacrinites basaltiformis*, but have the angles more rounded. From their exhibiting no marks of muscular corrugation at their exterior surface, and the points being of uniform thickness, I apprehend the fragments before me to have been full-grown columnar portions. I wave distinguishing it as a species, not having the means of furnishing a specific character; yet, should it prove such, I should propose for it the name *Pentacrinites subbasaltiformis*." p. 140.

I have a specimen of spatangus which is strongly marked, but very fragile, and was found at the depth of 250 feet. The same species was also found at the Highgate Archway; and the late H. H. Goodhall, Esq., informed me he had in his collection one from the London clay at Barton.

It is worthy of notice, that on comparing *Terebratula striatula* obtained from the well with specimens found in the chalk, there was no apparent difference†.

* Geological Transactions, 1st series, vol. i.

† Though this fossil is abundant in the London clay at Sheppy, and in the excavations for the Birmingham Railway, near Chalk Farm, yet it has been rarely found in the English chalk. Aug. 1837.

In the list appended to this notice are ten new species belonging to the class Conchifera*, and several species of *Microscopic foraminifera*†. In Plate VIII. fig. 2. 2 *a*., are represented two curious fossils. One of them is cylindrical, externally smooth, and shining, and is composed of dark brown spar; radiating internally like the Belemnite. The other is quadrangular, but with the angles rounded, and possesses internally the same structure as the first. Both effervesce strongly with muriatic acid. They are considered by Mr. J. De C. Sowerby to be remains of *Pennatulæ*.

The shells procured from "the rock" between the London and Plastic clays, are as follows: *Rostellaria lucida, Natica glaucinoides*, a *Nucula, Panopæa intermedia, Cardium nitens, Venus incrassata*, and a few casts apparently of the genus Pleurotoma. Lignite and scales of fishes also occurred. In some parts of the rock, were layers of calcareous spar, the surface of which was beautifully studded with crystals of pyrites. The bed contained a great many rounded flint pebbles, some of which were in a decomposing state; and a few of the same pebbles were imbedded in the lower part of the London clay at the depth of 230 feet. I believe it is not very usual to find a bed of sandstone between the two clays, but from its contained fossils, as the *Panopæa intermedia*, &c., there appears some analogy between it and the Bognor rock‡.

The plastic clay presented several varieties of colour, as red, grey, white, and yellow, variously intermingled. I examined it very closely without finding the slightest trace of organic remains. At the depth of 330 feet, the workmen arrived at a bed of sand, of a green colour, containing small flint pebbles, and at this part soft water was obtained, which gradually rose to within 200 feet of the surface. A steam engine is about to be erected on the spot, but whether an adequate supply of water will be obtained without the necessity of boring into the chalk, remains doubtful.

* Plate VIII. † Plate IX.

‡ In a paper by Mr. Richardson, (Geological Proceedings, vol. ii. p. 79,) much sand and green earth are stated to occur in the London clay near Herne Bay; and in Mr. Rofe's paper on the plastic clay of Reading, a rock is described at the top of the plastic clay. See p. 128 et seq. of this volume. I have also a specimen from Egham.

Organic Remains found in the London Clay in sinking a Well at Lower Heath, Hampstead.
(*London Clay.*)

Class.	Genus.	Species.	References and Synonyms.	Elsewhere.
Zoophyta	Flustra	——— *r**.	Pl. IX. f. 22	Highgate.
———	Cellepora	——— *r.*	——— f. 21.	
———	Desmophyllum	——— *r.*	(Ehrenberg.) Pl. VIII. f. 1.	
———	Pennatula	——— *r.*	Pl. VIII. f. 2.	
Radiaria	Asterias			
———	Spatangus	——— *v.r.*		
———	Pentacrinites	subbasaltiformis	(Miller's Crinoidea, page 140.) Pl. VIII. f. 3	Near White Conduit House, Islington, Richmond, and Kensington.
———	———	Sowerbii *r.*	Pl. VIII. f. 4.	
Crustacea	Cancer	2 species *c.*		Sheppy.
———	Astacus	——— *c.*		
———	Cytherina	barbata *v.r.*	Pl. IX. f. 1.	
Cirripeda	Pollicipes?	——— *r.*	Pl. VIII. f. 5. Pl. IX. f. 2	Highgate.
Annelides	Serpula	crassa *v.r.*	Min. Con. vol. 1. tab. 30	Ibid.
Conchifera	Teredo	antenautæ *c.*	——— vol. 1. tab. 102	Minster, Southend, Highgate, &c.
———	Panopæa	intermedia *r.*	——— vol. 5. tab. 419	Bognor.
———	Corbula	revoluta *r.*	——— vol. 3. tab. 209. f. 8 to 13	Barton Cliff.
———	Tellina	splendens *c.*	Sowerby, Pl. VIII. f. 6	Highgate and Sheppy.
———	Lucina	Goodhalli *r.*	——— f. 7	Ibid. Ibid.
———	Astarte	rugata *r.*	Min. Con. vol. 4. tab. 316	Ibid. Ibid.
———	Axinus	angulatus *r.*	——— vol. 4. tab. 315	Near White Conduit House, Islington, and between Vauxhall and Wandsworth.
———	Venus	incrassata *r.*	——— vol. 2. tab. 155. f. 1, 2	Brackenhurst, Hampshire.
———	———	tenuistriata *r.*	Sowerby, Pl. VIII. f. 8	Highgate and Sheppy.
———	Cardium	nitens *r.*	Min. Con. vol. 1. tab. 14	Ibid. Ibid.
———	Arca	nitens *r.*	Sowerby, Pl. VIII. f. 9.	
———	———	impolita *r.*	——— f. 10.	
———	Pectunculus	decussatus *r.*	Min. Con. vol. 1. tab. 27. f. 1	Ibid. Ibid. and Bognor.
———	Nucula	amygdaloides *c.*	——— vol. 6. tab. 554. f. 4	Ibid. and Southend.
———	———	inflata *r.*	——— vol. 6. tab. 554. f. 2	Ibid. Ibid. Ibid.
———	———	minima *r.*	——— vol. 2. tab. 192. f. 8, 9	Ibid.
———	———	similis *r.*	——— vol. 2. tab. 192. f. 3, 4, 10	Ibid. and Barton.
———	———	Bowerbankii *r.*	Sowerby, Pl. VIII. f. 11.	
———	———	Wetherellii *r.*	——— f. 12.	

Conchifera	Nucula	striata, *var.*		(Deshayes), Pl. VIII. f. 13.	
———	———	compressa	*c.*	Sowerby, Pl. VIII. f. 14.	
———	Modiola	elegans	*c.*	Min. Con. vol. 1. tab. 9	Bognor, Richmond Park Well, &c.
———	———	depressa	*r.*	——— vol. 1. tab. 8	Highgate.
———	Pinna	affinis	*r.*	——— vol. 4. tab. 313. f. 2.....	Ibid. and Bognor.
———	Avicula	media	*c.*	——— vol. 1. tab. 2.....	Ibid. and Sheppy.
———	———	arcuata	*v.r.*	Sowerby, Pl. VIII. f. 15.	
———	———	papyracea	*r.*	——————— f. 16.	
———	Pecten	duplicatus	*c.*	Min. Con. vol. 6. tab. 575. f. 1, 2, 3	Richmond and Hyde Parks.
———	———	corneus	*r.*	——— vol. 3. tab. 204	Stubbington.
———	Terebratula	striatula	*r.*	——— vol. 6. tab. 536. f. 3, 4, 5	Southend, Sheppy, &c.
———	Anomia	lineata	*r.*	——— vol. 5. tab. 425	Highgate, Barton, and France.
———	Lingula	tenuis	*r.*	——— vol. 1. tab. 19. f. 3	Bognor.
———	Natica	glaucinoides	*v.c.*	——— vol. 1. tab. 5	Highgate and Sheppy.
———	Dentalium	incrassatum	*c.*	——— vol. 1. tab. 79. f. 3, 4.....	Ibid. and Richmond.
———	———	nitens	*r.*	——— vol. 1. tab. 70. f. 1, 2.....	Ibid.
———	———	anceps	*r.*	Sowerby, Pl. VIII. f. 17	
———	———	Three species analogous to the Hampshire.		*r.*	
———	Vermetus	Bognoriensis	*v.c.*	Min. Con. vol. 6. tab. 596. f. 1, 2, & 3	Ibid. Sheppy, and Bognor Rocks.
———	Scalaria	reticulata	*r.*	——— vol. 6. tab. 577. f. 5	Ibid. Ibid. and Barton.
———	———	undosa, *var.*	*r.*	Sowerby, Pl. VIII. f. 18.	
———	Solarium	patulum	*r.*	Min. Con. vol. 1. tab. 11	Ibid.
———	Pleurotoma	———	*r.*		
———	Pyrula	nexilis	*c.*	——— vol. 4. tab. 331	Ibid. and Barton.
———	Murex	trilineatus	*c.*	——— vol. 1. tab. 35. f. 4, 5	Ibid. and Brentford.
———	Cassidaria	carinata	*c.*	——— vol. 1. tab. 6. Three upper figures ..	Ibid. and Sheppy.
———	Rostellaria	lucida	*v.c.*	——— vol. 1. tab. 91. f. 1, 2, 3	Islington Tunnel.
———	Auricula	simulata	*r.*	——— vol. 2. tab. 163. f. 5. 8.....	Barton.
———	Cancellaria	læviuscula	*c.*	——— vol. 4. tab. 361. f. 1.....	Highgate.
———	Ovulum	retusum	*v.r.*	Sowerby, Pl. VIII. f. 19	Ibid.
———	Nautilus†				
Pisces	Squalus, teeth	———	*c.*		
———	Raia, palate of	———	*r.*		

* *r.* signifies that the fossil was rare; *c.* common; *v.r.* very rare; *v.c* very common. The new species and varieties are distinguished by a reference to the Pl. VIII. and IX.

† The Foraminifera belong to the genera Nodosaria, Pl IX. f. 3 to 7; Articulina, f. 8 and 9 and 10; Frondiculina? f. 11; Marginulina, f. 12; Rotalia, f. 13 to 18; Cristellaria, f. 19; Miliola, f. 20.

Description of the New Species and Varieties figured in Plates VIII. *and* IX. *By Mr.* J. De Carle Sowerby.

Desmophyllum. This genus has been established by Ehrenberg, for a portion of those corals hitherto placed among the Turbinoliæ. The type of the genus given by Ehrenberg is the *Madrepora dianthus* of Esper, the *Caryophyllia dianthus* of De Blainville. It is distinguished from Turbinolia by having been attached at the base; and from the *Cyathina* of Ehrenberg (*Caryophyllia cyathus*), by the lamellæ being fasciculated.

Pl. VIII. fig. 1. (*a.*) The termination of the plates magnified. (*b.*) Section of one segment.

Pennatula. This fossil resembles the bony axis of *P. phosphorea*, (Lam.), which occurs recent on the British coast, and has the same structure, and the form of the section also varies from square to round, in the same bone.

Pl. VIII. fig. 2. (*a.*) The natural size. (*b.*) Magnified.

Pentacrinus subbasaltiformis, (Miller).

Pl. VIII. fig. 3. (*a.*) The principal stem. (*b.*) The side arm, nearly cylindrical and extremely long.

Pentacrinus Sowerbii, (Wetherell, MSS.). Joints unequal in diameter, 5-lobed, with two obscure tubercles on each lobe of the larger joints. Pl. VIII. fig. 4.

Polliceps? Posterior and lateral valves. Pl. VIII. fig. 5. and Pl. IX. fig. 2.

Tellina splendens. Ovate, convex, highly polished; beaks central, small; posterior extremity pointed, bent to the right.

Gregarious, occurring in thousands in Septaria. Pl. VIII. fig. 6.

Lucina Goodhalli. Subglobose, nearly smooth; anterior slope concave; lunette broad, flat, sunk; posterior slope convex, with one narrow and one broad groove on each side of it, meeting near the edge.

The young shell is sometimes very globose, at other times rather flattened. Pl. VIII. fig. 7.

Venus tenuistriata. Oval, gibbose, marked with nearly close, concentric striæ; beaks prominent, nearest the anterior extremity; lunette rather broad, pointed. Pl. VIII. fig. 8.

Arca nitens. Transversely oblong, convex, smooth; anterior portion small, rounded; posterior subcuneiform; front oblique; shell thin.

Some specimens have a few punctures, in which character they approach the next species. Pl. VIII. fig. 9.

Arca impolita. Transversely oblong, very convex, marked with longitudinal rows of punctures; anterior portion small, rounded; posterior rounded; front parallel to the hinge line; shell thin.

It approaches *A. cucullaris* of Deshayes, vol. i. p. 206, pl. xxxiii. figs. 1, 2, 3; but differs slightly in form, as well as in the teeth being all transverse. Pl. VIII. fig. 10.

Nucula Bowerbankii. Elliptical, convex, smooth externally, striated within; anterior extremity obliquely truncated, the slope filled by a large, pointed, nearly flat lunette; edge toothed; impression of the abductor muscles shallow. Pl. VIII. fig. 11.

Nucula Wetherellii. Suborbicular, transverse, gibbose, smooth; extremities pointed; beaks nearly central; margin obtuse, edge toothed.

The radiating structure of this Nucula, common to other species of the genus, is very conspicuous; but the inner surface is not striated as in *N. Bowerbankii*. Pl. VIII. fig. 12.

Nucula striata, var. (Lam., Ann. Mus., tom. vi. p. 126., tom. ix. pl. xviii. fig. 4 *a.*, *b.*—Deshayes, vol. i. p. 236, pl. xlii. figs. 4, 5, 6.) This variety is less equilateral than in Lamark's and Deshayes' figures. Pl. VIII. fig. 13.

Nucula compressa. Ovate, compressed, smooth; anterior portion very small; lunette wanting. Pl. VIII. fig. 14.

Avicula arcuata. Transversely ovate, arched, compressed, smooth, thin; nearly twice as wide as long; posterior ear large. Pl. VIII. fig. 15.

Avicula papyracea. Nearly orbicular, much compressed; concentrically waved; ears small, unequal.

An extremely thin pearly shell, sometimes assembled in considerable masses. Pl. VIII. fig. 16.

Dentalium anceps. Slightly arched, longitudinally ribbed towards the apex; one rib on each side of the arch prominent and sharp; smooth towards the aperture, which is round. Pl. VIII. fig. 17.

Scalaria undosa, var. (Min. Con. tab. dlxxvii. fig. 4). This differs from the variety figured in Min. Con. only in having the costæ less waved. Pl. VIII. fig. 18.

Ovulum retusum. Egg-shaped, short, transversely striated.

This differs from *Ovulum ovum*, the young state of which it very nearly resembles, in being shorter. We have not seen it with an inflected or thickened edge to the lip. Pl. VIII. fig. 19.

Cytherina barbata. Transversely ovate, gibbose, smooth, with several spine-like processes at the extremities. Pl. IX. fig. 1.

IX.—*Observations on the Strata penetrated in sinking a Well at Diss, in Norfolk.*

By JOHN TAYLOR, Esq., Treas. G.S.

[Read June 4, 1834.]

SOME interest has been excited by an attempt to bore for water at Diss in Norfolk, as no similar experiment had been made, and as the town had hitherto been ill supplied with water of good quality. This attempt was undertaken by my relative Mr. Thomas Lombe Taylor, for a brewery in which he is concerned; and as it has proved to be a successful experiment after considerable perseverance, and has ascertained the thickness of the chalk in that district, where it was hitherto unknown, it may be useful to record the particulars.

A well had been previously sunk to the depth of fifty feet, all of which was through clay, but sand was met with at the bottom, which yielded an imperfect supply of impure water; and as it was found extremely difficult to sink in this sand, cast-iron pipes were driven through it, which reached the chalk at the depth of 100 feet from the surface.

At this point the boring commenced, and proceeded through 100 feet of soft chalk without any stone, then 100 feet of chalk with flints at the distance of about a yard from each other. The next 100 feet were less flinty, but the flints which were found, were of a larger size than those above them.

Having attained a depth of 400 feet, and some apprehension being then entertained as to the probability of succeeding in penetrating the chalk, and of obtaining the object of the undertaking, I was asked to advise as to the prudence of going on with it. No opinion could be given as to the probable thickness of the chalk in a part of the country where it never had been proved; but it was, at the same time, certain that if it was passed through and the sand beneath it could be reached, a plentiful supply of good water would be obtained, and would probably rise to within a moderate distance from the surface. I, therefore, encouraged my relative to persevere, and the boring was continued to the depth of 615 feet, where the tools sunk rapidly for about five feet, as if there had been a cavity; but this was probably owing to the sand being put into motion by the sudden rise of the water through the

orifice which the tools had made. The water rose rapidly to within forty-seven feet of the surface, where it stood when I received the account.

The stratification determined by the boring appears to be as follows:—

Clay	50 feet.
Sand	50
Chalk without flints, soft and marly	100
Chalk with flints in layers of single stones, distant about a yard from each other	330
Grey chalk, with now and then a layer of white chalk, free from flints	60
Light bright blue chalk, rather approaching to clay, with white chalk stones	20
Sand	5
	615 feet.

It could not be ascertained whether there was any organized matter in the chalk, as the tools ground everything to powder.

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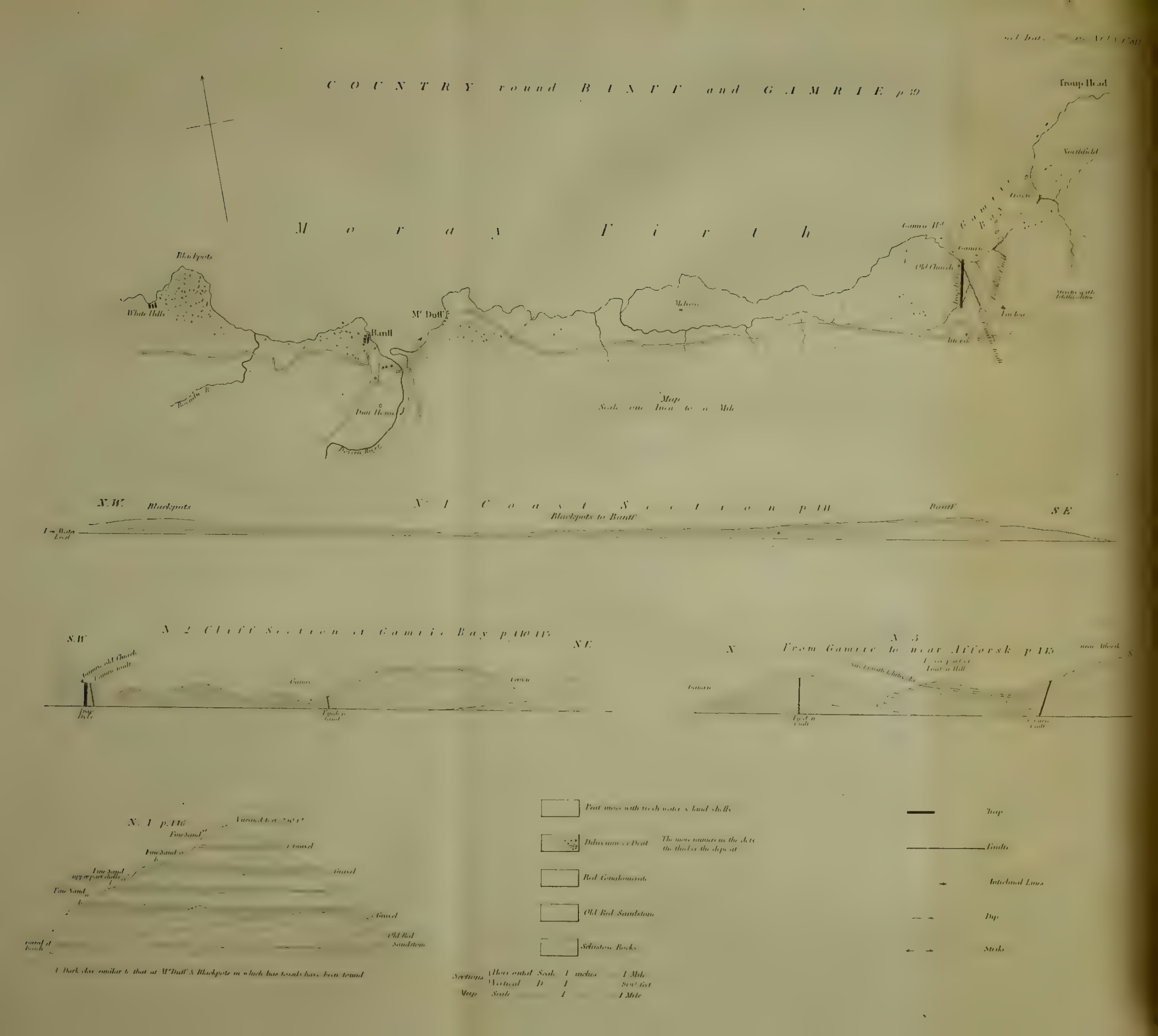

COUNTRY round BANFF and GAMRIE p 39
Moray Firth
Troup Head
Northfield
Gamrie Hd
Gamrie
Old Church
Blackpots
White Hills
Banff
Mc Duff
Melrose
Map
Scale one Inch to a Mile
N.W.
Blackpots
N 1 Coast Section p 111
Blackpots to Banff
Banff
S.E.
S.W.
N 2 Cliff Section at Gamrie Bay p 110 115
N.E.
N
N 3
From Gamrie to near Afforsk p 115
near Afforsk
N. 1 p. 116
Fine Sand
Gravel
Old Red Sandstone
Peat moss with fresh water & land shells
Diluvium or Drift
The more numerous the dots the thicker the deposit
Red Conglomerate
Old Red Sandstone
Schistose Rocks
Trap
Faults
Anticlinal Lines
Dip
Strike
Sections Horizontal Scale 1 inches 1 Mile
Vertical D 1 800 feet
Map Scale 1 1 Mile

X.—*On the Structure of the Neighbourhood of Gamrie, Banffshire, particularly on the Deposit containing Ichthyolites.*

By JOSEPH PRESTWICH, Jun., Esq., F.G.S.

[Read April 8, 1835.]

Introductory Remarks.

THE Ichthyolites of Gamrie were first brought before the public by Mr. Murchison, but, having been prevented from inspecting the precise localities, he contented himself with pointing out their existence; and obtained from Mr. Pentland, an account of their zoological characters*. M. Agassiz, during his recent visit to England, was much struck with the peculiar forms of these Ichthyolites, and expressed his opinion, that they belong to a deposit more recent than that in which the fossil fishes of Caithness are found, and has been shown by Messrs. Sedgwick and Murchison to pass down into strata of the age of the old red sandstone. Impressed with the importance of determining precisely the age of the strata containing the Gamrie fossils, and unable in consequence of other geological researches to do so himself, Mr. Murchison, on finding that I was about to visit Scotland, suggested the inquiry which led to this memoir. The result is, that the age of the fish-deposit, as determined by the position of the strata, coincides precisely with that suggested by M. Agassiz, from the zoological characters of the Ichthyolites†.

These fishes were first discovered in the summer of the year 1826, by Mr. Christie of Banff, and Mr. Dockar of Findon, who, while exploring the bed of a small brook, which flows through a narrow ravine and empties itself into the Bay of Gamrie, observed numerous, flattened, calcareous nodules frequently containing remains of fishes. Tracing these specimens up the brook, they arrived at a thin bed of bluish clay, which inclosed the Ichthyolites.

In my inquiries to ascertain the geological relations of this stratum, I have to acknowledge the attention and civility of the above gentlemen.

* Geol. Trans., 2nd Series, vol. ii. p. 363.

† See *postea*, p. 146.

Extent and Surface*.

The Bay of Gamrie is about nine miles east of Banff. The country is hilly, bleak, almost destitute of trees, and unenclosed. The extensive slaty districts, where not overlaid by drift, generally form moors covered with heather and furze; but where partially cultivated, they yield scanty crops of herbage; while the red sandstone, conglomerate, and drift constitute the arable lands. High and picturesque cliffs of slate rocks skirt the shore, forming numerous small headlands; between two of which, namely, Gamrie and Trouphead, is the small fishing hamlet of Gamrie or Garmstone (Pl. X. Map and Sec. No. 2.). The breadth of the bay is about one mile and a half, and its depth half a mile. The promontories by which it is formed, consist of high and craggy cliffs of micaceous and argillaceous schists, dipping rapidly south and south-west, whilst the centre of the bay displays a rough and broken range of red sandstone and conglomerates†; the bright vermilion colour of the former giving to the cliffs a singular and beautiful appearance. The slates and red conglomerates attain an altitude‡ of about 400 feet and the red sandstone of about 200 feet. The slates of Gamrie Head stretch inland and form a continuous range, intersected by a few ravines and small valleys; and are separated from the old red sandstone by a wild ravine, which ranges nearly due south. Along part of the eastern side of the ravine the red sandstone appears; whilst on the western side is an escarpment of slate rocks, and at the further end of it, are the bold and precipitous crags of the red conglomerate. The red sandstones form an abruptly undulating tract, much less elevated than those composed of the slates or the red conglomerates, the last attaining, at Findon, an altitude nearly equal to that of the encircling slate ranges, or about 600 feet above the level of the sea. Here and there are small outliers of superficial or drift clay and sand, the former containing lias fossils. To the south-west of Gamrie, is a small conical hill of this dark blue clay, resting upon the red sandstone; and another small similar tract, rests upon the slate rocks above Crovie. The streams take their rise either in the upper marls of the conglomerates, or in the overlying clay, and run through numerous ravines into the sea.

Schistose Rocks.

Describing the strata in the ascending order, I shall briefly allude to these

* Map and Sections, Plate X.

† The section being nearly at right angles to the dip, the strata appear to a spectator facing the cliff to be nearly horizontal.

‡ Not having had the instruments necessary to ascertain correctly the height of the hills, I can offer merely a rough approximation, founded upon a level taken from the coast up the bed of the rivulet to Findon.

ancient rocks, as forming the base on which the younger deposits were accumulated, and as exhibiting a type of the general character of the slate series of the district.

Upon a bed of light-coloured, fine-grained gneiss, exhibited occasionally in some of the anticlinal lines, reposes a beautiful variety of mica slate, consisting of slightly waved beds, alternately of a silver grey and light red colours, and occasionally studded with imperfectly crystallized garnets. These strata pass up into siliceous beds, consisting of a colourless quartz with a small quantity of hornblende; and are succeeded by argillaceous schists alternating with coarse roofing slate; which in turn are overlaid by strata of dark micaceous schist with waved surfaces, the uppermost beds being light grey and dark red, sandy and argillaceous.

The minerals found in this formation consist, as usual, of crystalline white quartz in the veins of the rocks; of a few small crystals of hornblende disseminated in some of the schists; and of small, imperfect garnets in the mica slate. Chromate of iron is also found, in the state of fine powder, in the sands at the base of the cliffs at Macduff, but the vein whence it was derived has not been discovered. An excellent section of the slates is exhibited along the coast from Blackpots to Gamrie; the lowest and the middle parts being displayed between Blackpots and Banff*, and the middle and upper parts between Banff and Gamrie. The strata are greatly contorted, and present, especially near Macduff and between Blackpots and Banff, numerous anticlinal and synclinal dips.

Old Red Sandstone.

In the cliffs behind Gamrie, and in the brook at Crovie, the upper beds of the schistose rocks pass apparently into the old red sandstone; strata of a dark purplish sandstone at first alternating with slates, sandstones and marls, and finally graduating into a bright red sandstone.

This deposit is of great thickness, and is well characterized by its lithological structure. Its lower beds form beautiful cliffs to the west of Gamrie, but the upper can be studied only on the banks of the streams below Findon; where, the friable sandstones and fine conglomerates of the higher part of this formation crop out. These upper strata dip slightly south-west, and are exposed in a succession of soft, red and yellow, slightly micaceous sandstones and marls, alternating with thin, subordinate beds, containing a few pebbles of quartz and slates. In the descending series, the beds become thicker, more compact, and of a brighter red streaked with yellow, and the subordinate conglomerates gradually disappear. That part of the formation which crops out on the coast, is peculiar (as I have before mentioned) for its fine bright red colour. In the lowest beds, the yellow streaks are replaced by round, light yellow spots, about the size of a shilling, and as regularly shaped. These beds are tolerably hard, and are used as a building-stone. I could discover no fossils in any part of this red sandstone.

Red Conglomerate and Clays with Ichthyolites.

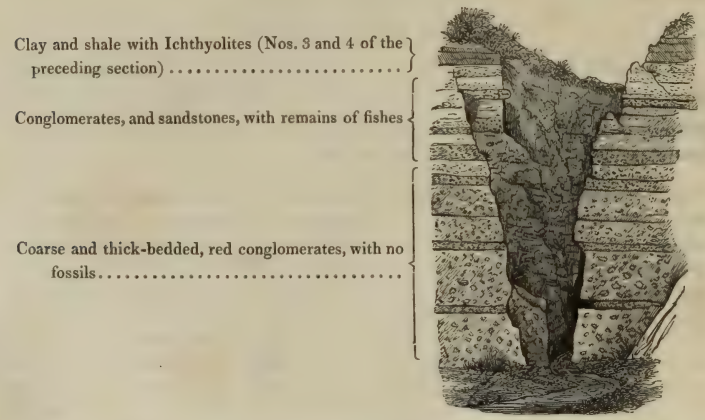
A good, and indeed almost the only section of the Ichthyolite-bed, is exhibited in a cliff, overhanging a small rivulet about 200 yards north of Mr.

* Pl. X. Sec. No. 1.

Dockar's farm at Findon. The following sectional list shews the position of this bed.

1. Fragments of schistose rocks imbedded in a coarse, ferruginous, slightly micaceous sand ..... 35 feet.
2. Red clay* ..... 2 —
3. Grey clay, with Ichthyolites ..... 4 —
4. Grey shale, slightly micaceous, with a few scales of fishes and traces of vegetables ..... 18 —
5. Red conglomerate ..... 5 —
6. Coarse, red, micaceous sandstone, with remains of fishes.. 3 —
7. Loose breccia, very similar to No. 1.

The outcrop of the underlying strata may be traced in descending the channel of the brook. They consist of thick beds of coarse, red conglomerate, separated by thin layers of micaceous, coarse, red and grey sandstone, forming a total thickness of about eighty feet. The old red sandstone is here brought up by a fault, which prevents the outcrop of the lower part of the red conglomerates; but a better section of the latter, appears in the deep ravine, about a quarter of a mile west of Mr. Dockar's. (See wood-cut).



The gradual passage of the clays, shales and sandstone into the thick, underlying conglomerates, may be seen there to great advantage. The conglomerates become coarser, and are generally harder as they descend; and at the same time the inclosed rolled fragments, present a greater mineralogical variety. Thus, the uppermost bed, which overlies the clay with Ichthyolites, consists almost solely of angular fragments of schistose rocks, varying in size from one to four inches, and imbedded in

* The red clay is of a variable thickness. Its colour appears to be owing to the percolation of water through the overlying ferruginous breccia.

a coarse, reddish-brown ferruginous and slightly micaceous sand. The sandstone underlying the clay is coarse, micaceous, and of a deep red colour, as is likewise the matrix of the underlying conglomerates. The rolled pebbles imbedded in them are commonly not larger than a marble, and consist principally of quartz and clay slate. The bed No. 7. of the first section, is, however, less compact, and more resembles No. 1. Below No. 7. (see section with wood-cut) the conglomerates gradually become coarser and harder, and inclose, with the pebbles of the schistose rocks, a few rolled masses of gneiss. Only a small portion, however, of the lower beds can be seen in either of the above-mentioned places, as the old red sandstone comes to the surface at a short distance from the outcrop of the Ichthyolite beds (Pl. X. Map, and Section No. 3.). The sandstone, at first sight, seems to rise from beneath the conglomerates, but is in reality brought into juxtaposition by a fault. Owing to the soft and friable nature of its upper beds, its presence is at once indicated, by the grassy slope of the sides of the ravines, instead of the bold and rugged escarpment presented by the conglomerates. The latter may be seen in fuller development in the cliffs between Gamrie and Crovie, which rise to the height of about 400 feet. Near Crovie they rest unconformably upon the lower beds of the old red sandstone (Pl. X. No. 2.), and dip at an angle of about 40° to the S.S.E., or from the face of the cliff as exhibited in the section; but upon approaching the fault, the strata rise rapidly westward or towards it. The beds are here of great thickness; and differ considerably from the upper beds in mineralogical composition, as well as in the size of the inclosed, rolled pebbles. The matrix is generally siliceous and extremely hard, occasionally of dark grey, and at other times of a white or red colour. In some of the lower strata it occasionally consists of a white, crystallized carbonate of lime. White quartz pebbles predominate in some beds, whilst the rounded fragments of granite, gneiss, micaceous and argillaceous schists and hornblende rock, are mostly of the size of a cannon-ball, but sometimes much larger; a few which I measured being from three to four feet in circumference. Rolled masses of a fine-grained, red and variegated sandstone, are also occasionally found in the lower part of the series. This phænomenon, together with the character of the cement of the lower beds, would indicate that the matrix of this part of the red conglomerates, had been principally derived from the destruction of the red sandstone upon which it reposes.

Such are the general lithological characters of the deposit. There can be no doubt, I should imagine, that the clay and shales inclosing the Ichthyolites* belong to the upper part of this series, passing, as has been shown, rapidly into the subjacent sandstones and conglomerates, in which occur remains of fishes, similar to those in the beds above. The Ichthyolites are disposed in the clay in nodular layers six or eight inches apart; and most of the nodules appear to have been formed upon a nucleus of a portion, or of an entire fish, whose remains are, however, generally in a very imperfect state. Scales of the

* The nodules are of a grey colour, flattish, and when they contain any portion of a fish, split by a smart blow of the hammer in the plane of the major axis, and are broken with difficulty in any other direction. The interior of most of the nodules is quite compact, and surrounded with a crust of fibrous carbonate of lime, occasionally speckled by green carbonate of copper. The species already figured in M. Agassiz's Poissons Fossiles, are as follows:—

Cheirolepis uragus, vol. ii. tab. 1^{e}. fig. 1, 2, and 3. *Cheiracanthus Murchisonii*, vol. ii. tab. 1^{e}. figs. 3 and 4. and *Osteolepis arenatus*, vol. ii. tab. 2^{d}.

same fishes with imperfect vegetable impressions, occur occasionally in the underlying bed of micaceous shale.

In the subjacent, red, micaceous sandstones, alternating with beds of conglomerate, fragments of the same fishes are also found; and it is only where these sandstones are entirely replaced by the conglomerates, that the fish exuviæ disappear. This absence might be expected, from the fragmentary nature of the deposit, which must have been accumulated by a body of water possessing great velocity and transporting power; and the friction of such numberless masses of rolled rocks, must have destroyed any animal or vegetable remains thrown amongst them. As we ascend in the series we have indications of alternating periods of comparative calm, during which the finer sandstones were deposited. As these periods increased in duration, the more favourable became the condition of the water for the existence of animals, until at last, during the slow and gradual deposition of the grey clay stratum, the entombed reliquiæ indicate an epoch, when the waters probably possessed but little velocity. This temporary calm was followed by another paroxysm, by which the shales and clay were covered to a great thickness with a friable, brecciated mass. This breccia forms the highest bed of the deposit in the district, and caps the hill upon which the small hamlet of Findon is built.

Trap Rocks.

A dyke of trap appears on the coast, near the junction of the red sandstone and the slate rocks not far from Gamrie church (see Pl. X. Sect. 2.), and ranges inland in a southerly direction. It is composed of a sienitic greenstone, and is from twenty to thirty feet across.

At Castle Hill, Gamrie, and at several other places in the same neighbourhood, and also on the schistose cliffs between Banff and Blackpots (see Pl. X. No. 4.), a dark-coloured tenacious clay, containing a few, subordinate beds of a light yellow sand, reposes almost horizontally upon the other rocks. I have been informed that lias fossils are found in this deposit*.

* In the paper originally read before the Society, this deposit was described as lias upon the authority of geologists in that country.—See Proceedings, vol. ii. No. 40. page 187, March, 1837.
See for a correction of this statement the Appendix to the paper, p. 146.

Faults.

Two great and important dislocations affect the continuity of the formations. By one of them, the Gamrie Fault, which ranges inland in a south-easterly direction (Pl. X. Map and sections 2 & 3), the highly inclined strata of the slate rocks, are brought successively on a level with the nearly horizontal beds of the red sandstone and red conglomerate, and at the point of contact, the edges of the sandstone and conglomerate are slightly turned up. The second, or Findon Fault, is well exhibited in the high cliffs immediately east of Gamrie (see Map and sect. 2 & 3.), where the micaceous schist, overlaid by the red sandstone, occurs also upon a level with the red conglomerate, and subsequently brings the red sandstone and conglomerates into contact. The schist, where it rises from beneath the red sandstone, dips at an angle of about 20°, but near the line of fault the strata are horizontal, and the beds of conglomerate against which they abut, are tilted at a considerable angle. This fault ranges in a south-westerly direction, crossing the ravine at the back of Gamrie. It may be seen at several other points near Findon.

A few less dislocations are visible in the cliffs and ravines, but they cannot be traced to any distance. That the upheaving, which produced these faults, was attended by a considerable lateral pressure, is denoted by the great tilting of the edges of the disjointed strata of the red conglomerates. I cannot speak positively as to the amount of disturbance, exhibited by these faults. That it was very considerable there can be no doubt; for in the Gamrie fault at the Old Church, we see the disjointed edges of the slates in contact with those of the centre of the old red sandstone series; whilst the Findon fault, has almost entirely thrown out the whole formation of red sandstone, indicating thereby a difference of level, amounting at least to several hundred feet. (See Pl. X. sect. 2 & 3.)

Conclusion.

Mr. Murchison directed my attention to the Gamrie Ichthyolites for the purpose of determining, as far as I was able, the age of the deposit in which they occur. From the observations detailed in the preceding pages, I consider that the strata belong to the upper series of a red conglomerate, more recent than the great mass of the old red sandstone described by Professor Sedgwick and Mr. Murchison*. The same observers have suggested, that the Caithness schists pass down into the old red sandstone; but as the conglomerates containing the Gamrie Ichthyolites lie unconformably upon a sandstone (considered to be the equivalent of the old red sandstone of

* Geological Transactions, 2nd series, vol. iii. p. 125, *et seq.*

England), I conceive, that it belongs to the carboniferous series, and most probably, to be the representative of the millstone grit or mountain limestone; and, therefore, to be younger than the Caithness schists*.

APPENDIX.

[Read May 3, 1837.]

In the preceding memoir, as read before the Society in April 1835, I stated, that lias fossils had been found in outliers of dark blue clay and sand, which in several places overlaid the older rocks, and upon that evidence, I suggested the beds might be of the age of the English lias. I had not then carefully inspected those deposits, and in the cursory examination which I made, I met with no fossils. Subsequent researches, however, having led me to doubt the correctness of my former surmise, and having again visited the district last summer, I now beg to retract that opinion, and to state briefly the conclusions at which I have arrived. It is true, that lias fossils are occasionally found in the cliffs of Blackpots, and in the beds of clay in other places around Banff; but they always occur in separate, rounded nodules and fragments of shale and limestone, associated with pebbles of the schistose rocks, and are disseminated in layers and patches in a dark, tough, or slightly micaceous clay. This argillaceous deposit, forms at Blackpots, cliffs eighty feet high, and rests upon sand which is rarely exposed; a bed of gravel usually intervening between the clay and sand.

The stratification of this accumulation is nearly horizontal, but irregular. Above McDuff it caps the hill to a considerable thickness, its lowest bed being grey loam, twenty feet thick, full of angular fragments of slate rocks. Patches of it range eastward by Melrose to Gamrie, and thence by Crovie to the back of Troup; but it is at Castle Hill, Gamrie, that the deposit is best developed. (Plate X. No. 4.) This hill is about 250 feet high, of a roughly conical form, and is exposed on one side by the cliff, and on two other sides by deep ravines. The base of the hill, to the height of about 80 or 100 feet, consists of old red sandstone, upon which reposes a series of sands and clays, and on the summit are the remains of a small vitrified fort. A few fragments of shells scattered on the grass about half way up the hill, induced me to make an excavation, by which I succeeded in obtaining several well-preserved specimens; and though the shells were rather numerous, they were

* Mr. G. Anderson of Inverness has recently informed me that Ichthyolites, the same as those of Gamrie, have been found by Mr. Miller near Cromarty, in a bed of clay, overlying the great system of conglomerates and sandstones

so extremely friable, at their first exposure, that it was very difficult to procure perfect ones. The following section exhibits their situation.

1. Soil and grey clay.
2. Yellow loam ..... 6 inches.
3. Gravel in ochreous clay ..... 8 ——
4. Dark grey clay, very tough..... 6 ——
5. Dark brown do. do. ..... 4 ——
6. Fine sand, with irregular patches of bleached shells, and occasionally gravel.

About fifty yards distant, the following somewhat similar section is displayed.

1. Loam, striped grey and yellow ..... 2 feet.
2. Gravel in ochreous clay (same as 3 of last section) $2\frac{1}{2}$
3. Dark clay 2
4. Sand 0

The shells, which are all recent, may be traced at intervals, and upon the same level around the hill. They consist of *Astarte Scotica, Tellina tenuis, T. Donax, Buccinum undatum, Natica glaucina? Fusus turricola, Dentalium Dentalis.*

The sands and clays vary considerably in thickness, and are accompanied by thin, subordinate beds of gravel, the lowermost of which reposes immediately upon the old red sandstone, and consists almost entirely of slightly rolled angular fragments of argillaceous slates with a few quartz pebbles. A second bed lies above the shells, and the pebbles are more rounded, and have been derived from a greater variety of the older deposits. A third, which occurs in the uppermost stratum of sand, is similar to the second. There are, besides these, a few small irregular layers in the upper sands. The most persistent of these beds is the lowest, which varies in thickness from four to thirty feet, and almost invariably accompanies the deposit; whereas the others are frequently wanting.

Flints (apparently chalk) are common on the beach, and it is probable that they were derived from some of the upper beds of gravel of this drift; for Mr. Christie of Banff informed me, that he had found them in the gravel on the top of McDuff Hill, and they have been met with also in the interior of the country.

From the above details it appears, that the series of sand and clays, was partly derived from the destruction and transport of the lias and lias marl. It is also evident that the disturbing power was of long continuance and of varying intensity. The rolled fragments, which generally underlie the transported, lias clay, indicate periods of paroxysms, when the waters, breaking and tearing up the lias and older rocks, bore them from their original to their present position; rolling and rounding, in their course, the harder fragments, and holding in suspension the finer clay, which, upon the cessation of the more violent action, subsided according to gravity, and thus formed a layer of fine clay resting upon a bed of gravel. The sands indicate a

period of calm; for in such a state only could the delicate remains imbedded in them, have been preserved.

This deposit appears to have been uplifted from the bottom of the sea in which it was formed, by a power not acting uniformly; for a gradual rise is perceptible in it, from the level of the shore at Blackpots, to Gamrie, where its base attains a height of 100 feet; indicating a disturbing power, whose energies increased as it tended eastward.

These and other phænomena, on the shores of the Moray Firth, prove that the level of the land has been altered several times, during recent geological periods. Some of these phænomena, indicative of an elevation more recent than the one just described, and well exhibited along the coast three miles to the west, and twelve miles to the east of Banff, I here purpose to notice briefly. At various points along this line, the effects of the last uplifting of the land are unequivocal, and prove a rise of the coast to an extent varying from six to twelve feet. To the west of Banff, at White Hills and Blackpots, may be seen, at the foot of the cliffs, and at about six feet above high-water level, a bed of shingle, which, in some places, contains large quantities of *Patella vulgata*, *P. lævis*, *Trochus ziziphinus*, *T. cinerarius*, *Littorina littorea*, and *Turbo retusus*, all of which inhabit the adjacent sea.

This change of level is also well exhibited in the cliffs of old red sandstone in the Bay of Gamrie, where remnants of a raised beach, four feet thick and ten feet above the level of high tide, remain in the indentations and hollows of the rock. This beach consists of flattened pebbles of the adjoining schists, precisely similar to those forming the present beach; but it contains no shells.

To this elevation may be ascribed the drainage of the former low lands of the country. Around White Hills* there exist, at a height of about twenty-five feet above high-water level, patches of a drained peat moss. It is composed of thin layers of peat, alternating with two seams of a fine gravel of white quartz grits, containing land and freshwater shells. The thickness of the whole does not usually exceed four feet. The peat is much decayed, and the shells, which are excessively friable, consist almost entirely of the *Succinea amphibia* and a species of Helix.

* See Map, Pl. X. The full extent of this deposit is not marked on the map.

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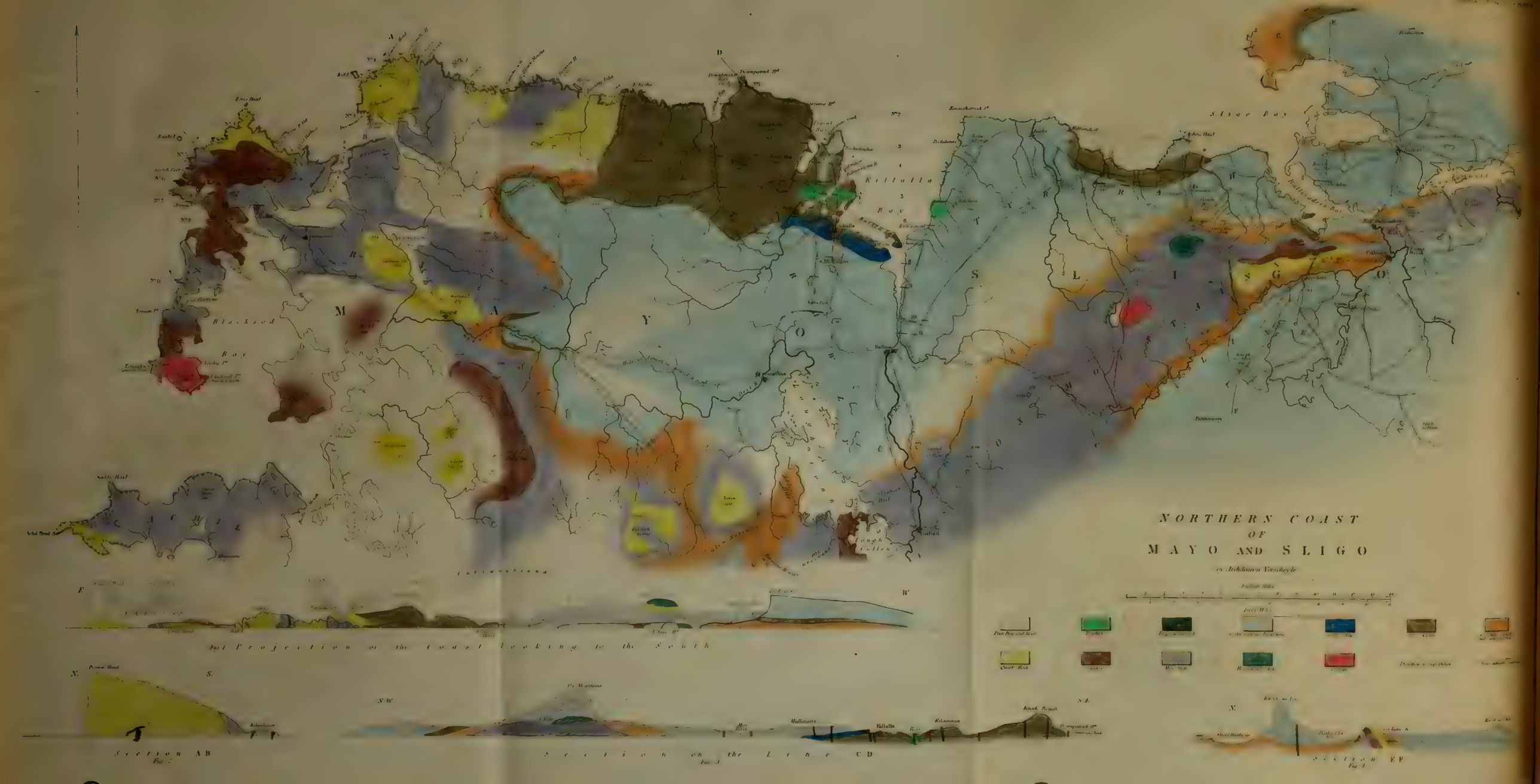

NORTHERN COAST
OF
MAYO AND SLIGO
by Archdeacon Verschoyle
Fig 1 Projection of the Coast looking to the South
Section AB
Fig 2
Section on the Line CD
Fig 3
Section EF
Fig 4
Blacksod Bay
Killalla Bay
Sligo Bay
Broadhaven
Ballina
Killalla
Ballysadare
Sligo
Inishcrone
Rathlee
Lough Talt
Lough Gill
Knocknarea
Ben Bulben
Dartry Mts
Ox Mountains
Nephin
Corraun Peninsula
Achill
Erris Head
Kid Head
Downpatrick Hd
Kinnaherrick Hd
Slieve Gamph
Benwee Head
Glenamoy
Belderrig
Ballycastle
Kilcummin
Ballysadare Bay
Raghly
Strandhill
Rosses Point
Drumcliff
Inishmurray
Inishmore
Inishbofin
Inishturk
Clare Island
Achillbeg
Duvillaun
Inishkea
Inishglora
Inishkeeragh
Inishgort
Inishcottle
Inishala
Inishmaan
Inishmeane
Inishbeg
Inishcrone
Rathlee
Lough Talt
Lough Gill
Knocknarea
Ben Bulben
Dartry Mts
Ox Mountains
Nephin
Corraun Peninsula
Achill
Erris Head
Kid Head
Downpatrick Hd
Kinnaherrick Hd
Slieve Gamph
Benwee Head
Glenamoy
Belderrig
Ballycastle
Kilcummin
Ballysadare Bay
Raghly
Strandhill
Rosses Point
Drumcliff
Inishmurray
Inishmore
Inishbofin
Inishturk
Clare Island
Achillbeg
Duvillaun
Inishkea
Inishglora
Inishkeeragh
Inishgort
Inishcottle
Inishala
Inishmaan
Inishmeane
Inishbeg

NORTHERN COAST OF MAYO AND SLIGO

by Archdeacon Verschoyle.

English Miles

Irish Miles

Peat Bog and Moor — Trachyte — Trap and Basalt — Carboniferous Limestone — Oolite Ditto — Slate & Grit — Old Red Sand and Conglomerate

Quartz Rock — Gneiss — Mica Slate — Hornblende Slate — Granite — Direction of Trap Dykes — Dykes actually

XI.—*Notices on the Geology of the North Coast of the Counties of Mayo and Sligo in Ireland.*

By ARCHDEACON VERSCHOYLE, M.A.

Communicated by Roderick Impey Murchison, Esq., P.G.S.

[Read November 7 & 21, 1832.]

THE country I propose to describe, comprises the northern districts of Mayo and Sligo. In constructing the map*, I have used for the former county, the excellent map of Mr. Bald, some fishery charts by Nimmo, and some local surveys; and for Sligo, a corrected copy of Larkin's Map. In connecting the two counties, I have used triangles resulting from the operations of the Ordnance Survey, most liberally communicated by Captain Portlock, with the permission of Colonel Colby; and where doubts and deficiencies in the details occurred, observations were made with a three-inch sextant, or Kater's Compass. The drawings (pp. 158. 162. 165. 167.) are from sketches taken on the spot, with every determination to sacrifice picturesque effect to accuracy.

The only notice which has been published respecting this part of Connaught, is a short but very able and accurate sketch in Mr. Griffith's paper on its Bogs, attached to the 4th Report of the Commissioners.

The Ox mountain ridge extends through the district from south-west to north-east. It is chiefly formed of mica slate, hornblende slate, gneiss, and quartz rock, the strata dipping rapidly to the south. At the base occurs a conglomerate, alternating with sandstone and slate clay; and overlaid by the carboniferous limestone, which extends westward from Sligo to the Nefin group. This group is the commencement of the primary tract, reaching northward and westward to the ocean. The section from Lough Talt to Downpatrick Head, displays the succession of strata†.

The Ox Mountains have a mean height of 1300 feet. On the north-west, the summits present abrupt rocky peaks; but the ravines are not of great

* Plate XI. † Plate XI. fig. 3.

depth, and rarely reach to the base of the chain, being gradually lost in the slope of the sides. On the south-east, the ascent is more gradual, less rocky, and streams are more numerous. The principal passes through the range, are from Colloony to Ballisadere; from Coolany to Baltra by Carrick-na-Shouock; from the barony of Liney to Skreen by Knock-a-Chree; from the same barony to Easky by Lough Eask; from Tubbercorry to Ballina by Lough Talt; and the Pontoon near Foxford.

The first, at Colloony, is very picturesque from the magnificent falls of the river over the limestone at Colloony and Ballisadere, and the much shattered and broken mountain of mica schist, called the Union Rock, which rises through the Union Wood; as if a course had been opened for the river by some violent convulsion, the further effect of which has evidently excavated the Bay of Ballisadere, assisted by the subsidence or removal of the limestone. The rocks surrounding Glen Lough at the foot of Benbulben, indicate a similar subsidence. On the south side also of the Ox range, the soil and even the strata of limestone, have been removed, and have probably formed materials for those immense ridges of water-worn gravel, called eskers, which are found in every part of the country. Near Tubbercorry, the surface for a considerable extent, is an almost naked limestone rock, like the shore of the barony of Tyreragh, presenting the same rounded cavities in the surface, as well as the same water-worn aspect, wanting only the sea-weed and the recent shells, to complete the identity. The drainage of this district is through the pass at Colloony, by the Owenmore, which, rising from the west side of Cash Corran, receives at the Union Wood the River Arrow, and before it reaches Colloony that from Coolany, whose source is near Knock-a-Chree. The steep and rocky escarpments of the passes through which these streams flow, with the debris scattered over the surface, mark the effects of a powerful torrent. At the falls of the river, at Colloony, the limestone ceases, and thence to Ballisadere mica slate is laid bare, to a depth of fifty-five or sixty feet, lower than the limestone above the falls. The bank of the river at Coolany, about five Irish miles from the sea, is 298 feet above high-water mark, and the average descent is, therefore, 59·6 feet in the mile. The grey peak above the Union Wood and the precipices of mica slate which skirt the river below, are memorials of the ruin which has taken place; while the fragments of the same rock so abundantly strewed in large boulders on the opposite side of the estuary of Ballisadere, exhibit both the effect and the direction of the torrent, which evidently flowed from the south-west into Galway Bay, spreading thence to the north-east towards Foxford and Sligo, as indicated by the perpendicular faces and broken strata of the limestone mountains, presented to the south-west and west; by the caves in Cash Corran, perfectly resembling those into which the waters of the Atlantic rush along the coast of Erris; and especially by the direction of the ridges of limestone gravel throughout the baronies of Liney and Corran, and the southern part of Mayo.

The second pass, Carrick-na-Shouock, derives its name from a bold and precipitous rock, which serves as a landmark to the harbour of Sligo, rising perpendicularly on three sides, and on the fourth with a very steep and difficult ascent. The road through the pass, winds over successive strata of quartz rock, gneiss, and mica slate, dipping to the south-east, and presenting to the north-west the broken edges of the beds.

Proceeding westward, we next reach the pass of Carrow-na-Skea, which crosses the ridge below Knock-a-Chree, the highest summit of this chain (1714 feet), and on the north side descends

into Tyreragh, behind Skreen hill. On both sides, the foot of the mountain is covered by a stratified quartzose conglomerate, which extends as far as the pass of Lough Talt.

The next communication between the baronies of Liney and Tyreragh, is through the mountain valley in which lies Lough Eask, the source of the river Eask. A small patch of granite borders the road which passes along the east shore of the Lough.

The river Moy having received, before it reaches Foxford, an accession of water from the Guishaden, as well as the lakes Conn and Cullen (about forty feet above high-water mark), passes, below the town, through the mountain chain between Carrick o'Hara and Shraheen Hill. The course of this river from its source to the Atlantic below Ballina, is about thirty Irish miles; and the descent being 300 feet from its head to high-water mark, it has a fall of ten feet in the mile, or one-sixth of that of the Colloony river; and probably from this cause, the effects of the stream are less striking, the pass through the mountain chain being also less abrupt: the soil likewise has not been so entirely removed as at Colloony.

Foxford stands on gneiss, from below which mica slate rises, at the hills of Shraheen and Burran on the Moy. Lough Cullen communicates with this river near the town, having received the drainage of Lough Conn, by the rocky strait at the Pontoon, where the waters have forced a passage through the beds of gneiss, leaving immense boulders scattered on the surface, even to the summit of the hills over the pass.

It is remarkable, that throughout this district clay slate is never found either *in situ* or boulders.

In the cliffs along the sea coast (see Pl. XI.) the succession of strata is satisfactorily exposed. Commencing at the promontory of Tarmon in Erris, a district where primary rocks only occur, granite is quarried near Blacksod Point, and lies in beds which may indeed be called strata. The felspar is brick red, the quartz smoke grey and translucent, and the mica black: no imbedded minerals have been observed. In a small inlet on the shore, at the west end of the hill, below the Signal Tower, mica slate appears, dipping 15° to the east, and abuting against the face of the granite beds, which incline to the west 45°; and in a narrow cove, south of this inlet, the dip of the mica slate increases to 70°, its direction becoming south. Numerous veins of granite penetrate the slate, and in some instances contain fragments of it.

Proceeding to the north-east, the coast presents only a succession of sand-hills and beaches, except where a few reefs of gneiss or mica slate project into the sea. The first range of cliffs is at Annagh, the south headland of Frenchport, and consists of mica slate traversed by a trap dyke; but the north headland of this inlet is formed of gneiss, composed of red felspar and black mica. On approaching Scotchport, garnets appear, the mica increases, and the felspar gradually diminishes, till the gneiss becomes mica slate, which graduates into quartz rock, in the direction of Erris Head*. This formation constitutes the lofty and broken cliffs to Broad Haven, with the exception of a few places,

* For additional observations on this part of the coast see p. 160.

where mica slate occurs. From Knocknalina the shore is low, consisting chiefly of peat, and the subsoil is a ferruginous clay, resting on fragments of mica slate. Near Belmullet, on the isthmus separating Broad Haven and Blacksod Bay, are vertical beds of mica slate, pierced and disturbed by the continuation of the trap dyke at Annagh. This mica slate, with many variations and transitions into gneiss, continues till it disappears beneath the clay banks of Blacksod Bay. The eastern side of Broad Haven and the mountains of Kilcommon, are also mica slate, which at Donkeehan, on the north side of the haven, presents nearly vertical strata, inclining to the north, and striking east and west. Its texture is close and fine-grained, and colour greyish yellow. The small peninsula which stretches to the south from Kilgaligan, and terminates at Rinroe Point, is formed of this rock, traversed by a trap dyke. Continuing along the coast northward, the mica slate is soon succeeded by quartz rock, a prolongation, probably, of the Erris Head strata. It underlies the mica slate, becoming nearly vertical, and continues to Portacloy, but varies much in its dip. At the first headland, to the east of Kid Island, a trap dyke rises from the sea, and will be hereafter described.

Pursuing the examination of the coast to the eastward, the quartz rock continues up the narrow harbour of Portacloy, the western cliff of which is a truncated cone, connected with a narrow isthmus terminating about twenty feet below the summit, and accessible only by steps hewn in the rock. At the west side of this headland, called Doonminulla, is a magnificent cavern, into which the sea flows through an arch about thirty feet wide and twenty-five high, the roof within, rising in a dome of above forty feet, and the length and breadth of the hall or chamber, averaging about sixty-five or seventy feet. This opening was probably produced by the disintegration of a mass of trap and the action of the waves; as arches and passages, in other parts of this coast, clearly exhibit such decomposition in progress. Between Portacloy and the next landing-place, Porturlin, a small and very narrow inlet, mica slate prevails; but across the mouth of the inlet a vein of trap passes, and is again seen in the headlands next to Benmore. From the latter point the coast continues precipitous, and is composed of mica slate or quartz rock graduating insensibly into each other. In the perpendicular face of Benwore headland, the beds diverge from a point beneath the surface of the water, like the rays of an expanded fan, probably influenced by the same dyke, which separated Horse Island from the mainland. At the east side of Balderig inlet, a bed of very compact trap is found below high-water mark, and seems to have been protruded between the strata of quartz rock, and to have proceeded from the Horse Island vein. Thence to Conoghrea there is nothing

very interesting; but we there arrive at the termination of the inferior and the commencement of the intermediate order of rocks, including the carboniferous limestone; and these beds extend without interruption to Ballyshannon in Donegal.

From Fohurlin to Kilcummin, west of Killalla Bay, the cliffs present strata of sandstone, occasionally containing vegetable remains, and alternating with shale and argillaceous limestone; the whole dipping regularly to the south-east, when undisturbed by the intrusion of trap veins.

Very fantastic scenery, resembling arches, and towers, as well as caves of unusual forms, abound along this part of the coast. In some places, the sea, having penetrated the lower strata of the cliff to a considerable distance, has excavated spacious caverns, at the extremity of which a portion of the roof having fallen and been also washed away, an opening to the surface has been formed, by means of which the waves are seen to rush with violence against the end of the cavern. One of these excavations extends across the headland of Downpatrick, a distance of about 500 yards, and in the centre, a large chasm, or, as it is locally called, a pigeon-hole, has been formed, and is 120 feet deep to the water below. Downbrista rock, which resembles an enormous, insulated, and inaccessible tower, 130 feet high, has been probably separated from the main land; as the continuation of a wall, whose remains are plainly traceable to the very edge of the cliff, stands on the summit of the rock. The powerful surge of the Atlantic breaking on the north-west face of the headland, also 130 feet high, rises with such force and momentum as to tear up the rocks at the summit edge of the cliff, and in many instances to raise on their edges, fragments from among the debris, weighing at least half a ton. In the north-westerly gales, the spray ascends in a magnificent column, to twice the height of the precipice against which the swell breaks, and is carried to a great distance inland.

On the west side of Downpatrick Head, between Downbrista Rock and Buntraher Bay, the Horse Island Dyke (No. 2.) is again seen; and on doubling the head, passing eastward, another dyke, a continuation of No. 1, lies against the cliff, like an immense wall. On the sandy beach of Tracal Bay is a creek, called Poolagranny, which deserves careful examination. Proceeding around the promontory of Kilcummin, a range of elevated and perpendicular precipices, bounds the coast as far as Poolaclogher; whence the shore is chiefly composed of gravel in waved beds, apparently much disturbed. Crossing the estuary of Palmerstown River, and following for some distance the sandy beach of Ross, the porphyry or trachyte formation, described in the 2nd section, occurs. Thence to Enniscrone, the Bay of Killalla, is bounded by the

sand-banks of Bartra Island and Scurmore, to the north of which, on the Sligo shore, is a continuation of the trachyte, first seen in Ross. From this point to Ballisadere Bay, the coast is composed of mountain limestone and the associated beds of sandstone. These strata are strikingly displayed in the precipitous sides of Knock-na-ree, to the east of Ballisadere Bay, and are streaked horizontally with beds of light grey rock, tinged with various shades of purple and yellow; and are skirted by a talus of fragments from the cliff above.

I have thought it convenient thus to separate the general sketch of the district, from those geological details, which are the more immediate object of this communication.

Second Section.

In considering the subject of this section, I adopt the arrangement of the Rev. William Conybeare, in his Outlines of the Geology of England. Commencing, therefore, with the highest formation in the district, the following series will be described:

Intermediate order	A. Carboniferous limestone. B. Ditto oolitic. C. Calcareous and argillaceous shale and grit underlying the limestone. D. Old red sandstone and conglomerate.
The inferior or primary rocks	E. Quartz rock. F. Gneiss. G. Mica slate and hornblende slate. H. Granite.
	I. Trap rocks, porphyry, and basalt.
	K. Trachyte.

Intermediate Order.

A. *Carboniferous Limestone.*

This formation prevails on the north and south of the Ox Mountains. Benbulben (1697 feet) and Knock na Ree (1057) on the north of the chain; and Knock na Shee (480) on the south, are entirely formed of it. The lower beds contain nodules of black chert, and invest the organic remains which abound in limestone throughout Ireland. It varies in texture from compact to highly crystalline, and in colour from grey to light brown; its specific gravity ranging from 2·670 to 2·685. Arragonite, fluor, brown spar, pyrites, and quartz crystals are often imbedded in it, or line rifts and fissures. A vein of sulphuret of lead accompanied by blende and iron pyrites, has been worked at Ballisadere, but is now abandoned. It is said to have been very rich in

silver. About eighty years since, another lead mine was wrought at Luggawarry, on the north face of the Ox Mountains, near the pass of Carrick na Shouock. The level and some shafts are still open, and the ore was found near the junction of the limestone with the subjacent rocks. Organic remains abound in the formation, some occurring in it exclusively, as far as I have examined the midland parts of Ireland. Among these, polyparia are prominent, especially a gigantic species of Cyathophyllum; and among the shells I have seen two specimens of a very large Euomphalus, armed with formidable spines*, also many species of Productus, Spirifer, and Terebratula. In the Hill of Skreen, among the lower beds of this rock, near the junction with the subjacent conglomerates, are some thin strata containing numerous quartz pebbles cemented by limestone; and beneath these are layers containing shells, but no quartz pebbles. In the neighbourhood of Killalla is the following peculiar formation, which I have not observed elsewhere. It is interposed between the limestone and the older sandstones.

B. *Oolite of the Carboniferous Limestone.*

This deposit, which lies below the limestone from Moyne to Rathrea, varies in colour from iron grey to dark smoke grey; and is composed of granular concretions not larger than mustard-seeds, but, under the microscope, appear to consist of concentric laminæ. Its durability as a building material, is proved by the ruined abbey at Moyne, the arches, pillars, and smallest mouldings of which, retain the most delicate touches of the chisel. Marine exuviæ occur in this rock, but so comminuted that the genera are scarcely determinable. It contains also, though rarely, carbonized and pyritous, vegetable remains, resembling reeds and the leaves of the Iris; also nodules of black shale containing particles of pitch coal. Sometimes cavities occur, lined with arragonite, in fibrous radiated concretions. The beds are frequently separated by layers of brownish slate clay, varying in thickness, and interspersed with fragments of black slate clay, not at all water-worn. This oolite, as already stated, is very limited in extent, being found only from Moyne by Killalla to Rathrea. In some parts of the county of Sligo, the lower beds of the carboniferous limestone are highly crystalline, and much resemble this rock; but a magnifier immediately detects the absence of the spherical concretions.

At the outcrop of this deposit along the shore, between Killalla and the Abbey of Moyne, is a breccia composed of angular fragments of oolite, im-

* A species somewhat analogous is figured in the 2nd part of Prof. Phillips's Geology of Yorkshire, Pl. XIII. fig. 5.

bedded in an argillaceous cement. It occupies the spaces between large masses of the same rock, thrown confusedly together. The edges of the beds are elevated and much fractured, while their recurrence to the north, to which point they rise, indicates a subsidence or fault ranging east and west. The beds of peat and bog-timber, found below high-water mark in Killalla Harbour, may be connected with the fault. Near this place the sandstone emerges from beneath the oolite in rude columnar masses, much disturbed, and forms the commencement of the grit and shale beds described under the next head.

C. *Calcareous and Argillaceous Shale and Grit.*

The mountain limestone rests on alternating layers of sandstone, slate clay, and argillaceous limestone, except where the oolitic strata intervene; and the lower beds of grit, graduate, in some places, so insensibly into the subjacent quartz rock, that the limits of the two formations are very difficult to determine. At the western boundary the transition is gradual, and were it not that the strata of quartz rock at Glen Lassera, are unconformable to the beds of sandstone, the demarkation could scarcely be ascertained. The conglomerate of the old red sandstone is also absent there; but along the foot of the Ox Mountains, it is interposed between the grit and shale beds and the older strata. To detail the succession of layers is impossible, but two examples, taken from Ross and Moyne, may be instructive; and Mr. Griffith's Memoir on Mayo, in the Reports of the Bog Commissioners, made in 1814, furnishes the details at Balhorig in Erris*.

Section at Ross, near Killalla.

	Ft.	In.
Sandstone, highest bed	12	0
Claystone	5	0
Clay parting	0	5
Wacke	0	8
Yellow Clay	0	5
Wacke	0	9
Red Clay	0	2
Green, Sandy Clay	0	7
Claystone	2	0
Shale	0	9
Sandy Clay	0	6
Wacke	0	3
Sandy Clay	1	0
	24	6

	Ft.	In.
Brought forward	24	6
Schistose Sandstone	2	0
Claystone	6	0
Schistose Claystone	1	0
Wacke	5	0
Sandstone, with clay nodules imbedded	4	0
Yellow Clay	0	9
Wacke and Sandstone, with wood in a bituminized state	8	0
Black Shale	1	6
Claystone (lowest bed exposed)	10	0
	62	9

* Report, p. 179.

Section at Moyne, north-west of the Abbey.

	Ft.	In.
Oolite	35	0
Black Limestone, containing Cirri, clayey and friable	2	0
Sandstone in beds	5	0
White Shale	2	0
Sandstone	1	4
Sandstone and Shale, in thin layers	2	0
	47	4

	Ft.	In.
Brought forward	47	4
Alternate beds of Shale and Limestone	3	8
Calcareous Sandstone	1	10
Shale	0	8
Argillaceous Limestone	1	8
Shale	1	8
Ochrey Sandstone	1	0
	57	10

There is a striking resemblance between these grit and shale beds, and those which accompany coal; but they lie decidedly below the great limestone, over which all the Connaught coal district is placed. Their total thickness may be estimated at 1700 or 1800 feet.

The most instructive sections are exposed along the coast from Ross, near Killalla, to Port Conoghrea, where the quartz rock is first seen. In many quarries, the surface of the grit beds exactly resembles a sandy beach deserted by the tide, presenting the same waved, ripple marks.

Beneath the varied succession of strata, which underlie the carboniferous limestone, is generally found the

D. *The Old Red Sandstone and Conglomerate.*

This rock occurs uniformly along the base of the Ox Mountains, both on the north and south declivity; but, at the shore on the confines of Erris, where the intermediate and primary strata join, it has perhaps either never existed, from the absence of the causes which influenced its deposition elsewhere, or it has become identified with the lower portion of the grit, by a change in the grain and texture. In general, the strata are very distinct, though composed of large pebbles of quartz, jasper, and primary schists imbedded in a tenacious cement. The argillaceous soil formed by the decomposition of the matrix of the conglomerate, is stiff, cold, and sterile. I have not observed any organic remains. The conglomerate graduates, in many places, insensibly into the subjacent quartz rock, especially on the south declivity of the Ox Chain, where the two formations lie conformably on the inferior strata; but on the northern slope, the conglomerate rests on the edges, or outcrop of the older beds. This position may be very distinctly seen at the foot of Knock-a-Chree, above Drimnagoole, where the mica slate dips to the south, to which point the beds of old red sandstone rise, lying unconformably on the edges of the schist, and followed by the grit, shale and carboniferous limestone, in regular and parallel succession. In Glen Co, on the banks of the Owenmore River, in Erris, this rock emerges from under the series described by Mr. Griffith, and lies on the quartz rock, which pre-

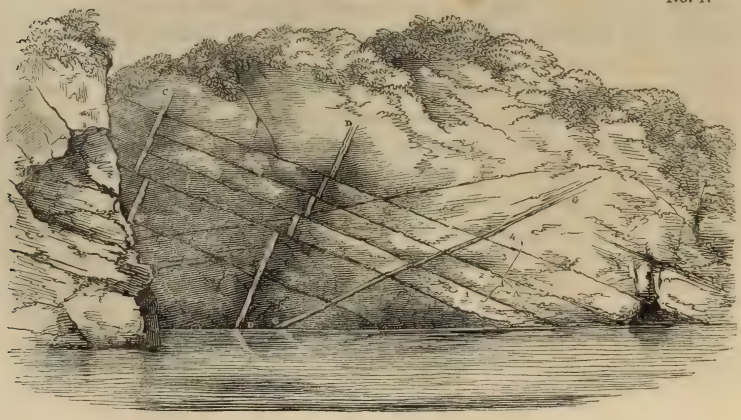
vails to Bangor. The hill of Addergool on Lough Conn, and Glen Nefin, on the flanks of the Barnagee Mountains (a prolongation to the south-west of the Ox Chain), are old red sandstone, in regular beds, though remarkably coarse, being formed of rolled pebbles of unusual dimensions. The thick beds of peat which generally cover the declivity of the mountains, preventing an exact knowledge of the boundaries of the rocks, the demarkations can be ascertained only in the ravines, where the streams have removed the bog, soil, and decomposed strata.

The Inferior or Primary Rocks.

E. *Quartz Rock.*

This formation overlies the gneiss in many places along the south declivity of the Ox Mountains. It is generally composed of very fine, white, quartz grains, firmly compacted, and free from extraneous mixture; and it is laminar or schistose in structure. This may be considered the purest variety, and of such Nefin in Tyrawly, 2639 feet high, consists; also the vertical beds in the headlands, east and west of Broad Haven. In other places it is mingled with white, compact felspar, the laminæ being thicker and less regular; and mica also enters into the compound, which then graduates into gneiss. Rising from below the old red sandstone, on the banks of the Owenmore, in Erris, it prevails around Bangor and the south shore of Carromore Lake; but on the east bank mica slate appears. The northern part of the Mullet is also quartz rock; and in a perpendicular cliff, at a place called Mycreeny, between Blind Harbour and Erris Head, are several very interesting and perplexing, shifted quartz veins. (See the following sketch, No. 1.)

No. 1.



The derangements represented in the sketch might have resulted from repeated slips of the strata in varying directions; suppose (see diagram No. 2.) the aggregate of beds marked A 1, 2, 3, 4, to have slid together in the direction E E, the interruption at C would be the result; after which a series of successive slips of the individual beds A 1, 2, 3, 4, in the altered direction F F, parallel to the vein C C but oblique to D D, would displace the latter in each bed, as represented in the plan; while G G, in consequence of its position, so much inclined to the planes of those strata, would be differently affected, and the breaks in its continuity might be scarcely perceptible*.

No. 2.

A great part of the coast from Broad Haven to Glen Lassera consists of quartz rock, varying considerably in dip and direction. East of Broad Haven, from Kilgaligan to Kid Island, the beds are nearly vertical, and of pure white, granular quartz, in which I saw no vestige of imbedded minerals. At Sheeanemore, between Porturlin and Balderig, is a remarkable slip, the western portion of the cliff being depressed about 300 feet. At Glen Lassera this formation disappears beneath the intermediate rocks, and recurs no more along the coast to the eastward.

F. *Gneiss.*

This rock is well characterized at the Pontoon Bridge between Lough Conn and Lough Cullen; also at many places in the peninsula of Erris, and in the mountains at Mulli na Shee above Coolany; but sometimes it graduates into mica slate. At the Pontoon the mica is black, and the foliated structure is strikingly displayed; while the occurrence of imbedded crystals of red felspar, gives a porphyritic character to the rock. The beds dip from 10° to 45°, and 60°, to the south-west, the prevalent direction throughout the Ox Chain.

* The explanation offered in the text accords with that proposed by the late M. Schmidt, to account for the phenomena of veins having been apparently shifted in opposite directions, without any intermediate break (1 C. D 1, Exposed Section, and wood-cut No. 1.); and depends upon the strike of the veins not being parallel (C C and D D of Plan). In the above case, at Mycreeny, the movements are supposed to have been in the direction of the arrows, or towards the front of the cliff (No. 1. wood-cut); and the upper or shifted portions to have been removed.

In Erris, behind the vicarage at Tarmoncarra, the rock is well exposed in the cliffs. The strata range north-west and south-east, and though when considered generally, the gneiss appears to lie above the mica slate, and below the quartz rock, yet when examined in detail, frequent alternations and transitions are observable, even in the space of a few perches; so that it is only from an inspection of the whole deposit, its nature and character can be determined. For instance, at Annagh, the south headland of Port-na-Frankagh (French Port), mica predominates, and the gneiss approaches in aspect to mica slate, while the north point presents gneiss, distinctly marked, abounding in red felspar, with black mica; and more northward, near Scotch Port, it is studded with garnets, and the mica coalesces into small feathery crystals, while the felspar has diminished into fine grains, detectable only by a magnifier. Proceeding along the shore, hornblende gradually becomes a component, and even occasionally the predominant ingredient, and sometimes the mica slate contains crystals of sahlite. Between Scotch Port and Donamoe is, however, a sudden change. A narrow fault or fissure, scarcely a foot wide, filled with a clayey breccia, apparently derived from the detritus of hornblende and gneiss, and ranging in an easterly direction, cuts through all these beds, having on the south the hornblende schist, and on the north, mica slate, perfectly distinct, and containing those peculiar plumose concretions of mica, alluded to above. From this sudden variation, we may conclude, that an elevation has taken place at the north side of the fault, produced, probably, by the same operation which erupted the dykes parallel to it; and that the mica slate and gneiss of Port-na-Frankagh, or French Port, are here forced up to the surface; the coast rising once more into mica slate cliffs, in which the mica again diminishing and the felspar reappearing, the rock passes into gneiss. Oxydulous iron in laminæ is met with here, accompanied by druses of felspar crystallized in oblique rhomboidal prisms. From this point mica again predominates, and Donamoe consists of mica slate. Proceeding to the northward, the mica and the felspar decrease gradually, and the beds pass into quartz rock, which, towards Erris Head, as already detailed, exclusively constitutes the sea cliffs. In the eastern part of the district, at Mulli-na-Shee, below which the road from Coolany to Tyreragh passes, the same transition from quartz rock to mica slate is seen, the latter containing an unusual ingredient, in small crystals of asbestos disseminated through the mass, and accompanied by minute prisms of felspar; schorl and calcareous spar also sometimes occur. The beds under these abound with garnets. The entire series, from the conglomerate to the mica slate, dips about 15° or 20° to the south-east, which is the general inclination of the strata in the Ox Mountains.

G. *Mica Slate and Hornblende Slate.* H. *Granite.*

Mica slate and its subordinate strata constitute the prevailing rocks in the Ox Chain and Erris Mountains. At the sea shore below the western declivity of the hill of Tarmon, which forms the southern point of Mullet, the slate is penetrated by granite veins. An instructive example of this interference appears in a small cove, about four yards wide, near a point called Toneadoon. At a bifurcation of the vein, a small detached fragment of mica schist, is entangled in the granite, the laminæ being in a direction different from those of the surrounding schist. The vein is seen at both sides of the inlet, and it has rendered the schist looser in its texture, as well as somewhat friable; the laminated structure also is partially obliterated, and the mica is replaced by a mineral resembling hornblende. This change takes place gradually in the neighbourhood of the vein, which is highly crystalline, the felspar being in large rhomboidal crystals of a flesh red. The granite is laminated, the mica is greenish white, and the quartz nearly translucent; and the layers are parallel to the sides of the fissure, but coarser and larger in the middle.

It is evident, the rock has been disturbed subsequently to the formation of these veins, as a vertical slip has almost broken their continuity near the extremity next to Tarmon Hill. The mica slate there dips 70° to the south, and appears to have been shifted about half the breadth of the vein. It contains also veins of quartz, sometimes four feet wide. The junction of this rock with the granite, can also be examined at an inlet north of the signal tower, the mica slate dipping 15° to the east, and the edges of the beds abutting unconformably against the mass of granite. At Doonaniron, north of Broadhaven, the quartz rock dips 60° to the south, and upon it the mica schist lies conformably, but distinctly separated; the quartz beds being unusually pure and unmixed with extraneous matter, and the schist abounding remarkably in mica. Mica slate prevails through the district south of Kilcommon, as far as the banks of the Owenmore; and continuing thence to the river Munneen, the boundary probably ranges by the foot of Corslieve, Nefin, Knock-na-Ree, and Shraheen Mountains, to the Ox Range, where, in the gap of Lough Talt, beds of the schist approach in composition hornblende rock. But this is merely a local variety. Above Lough Eask garnets abound, and pinite sometimes occurs; and to the eastward asbestos is found.

On the north coast, mica slate forms the eastern cliff at the entrance of Portacloy, where the beds are most capriciously contorted by the influence of the first dyke; and it extends to Porturlin, but is there succeeded by quartz rock, which prevails to Benmore. At this point mica slate reappears, rifted and disturbed by the intrusion of trap, which rises perpendicularly from the sea two thirds of the height of the cliffs, and then turns off for a short distance

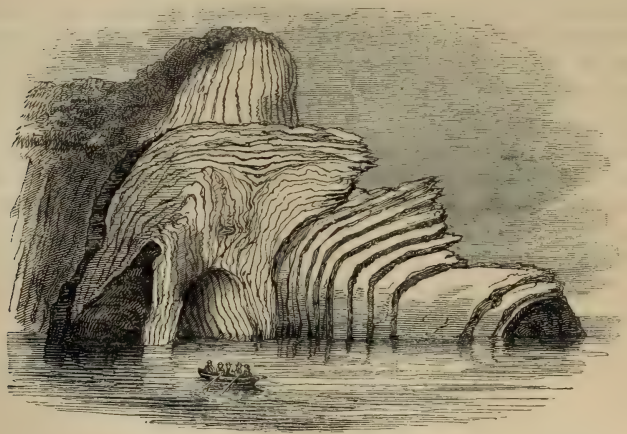
in conformable stratification. At Balderig Inlet the mica slate disappears, recurring no more on the coast.

The inferior rocks, granite, gneiss, mica slate, and quartz, just described, frequently graduate so insensibly into each other, that the observer is inclined to allow them a common origin, modified only by variations in the proportions of the ingredients of which they consist; for instance the Erris granite in most instances passes into gneiss, the gneiss into mica slate, and this into quartz rock. Below the signal tower of Tarmon, veins of that granite, however, pierce the mica slate, producing decided and obvious proofs of protrusion and derangement, and at the exposed junction of these rocks the mica slate is unconformable in stratification, the edges of its layers abutting against the inclined face of the granite.

I. *The Trap Rocks, Porphyry, and Basalt.*

These are the most interesting and remarkable rocks of the district. They form dykes, unexampled, I believe, for length, directness, and parallelism, and for their varied effects on the adjacent strata*. Their strike is nearly east and west, differing only 4° or 5° to the north of west. I commence their description with the most northerly, which may be distinguished as No. 1.; and proceed with my details in a direction from west to east.

No. 3.



Strata of mica slate bent over projecting masses of trap at Attatovick Point.

* See Map, Plate XI*. The points at which the dykes were actually seen are marked by a line; and the supposed connexion or continuation by dots.

No. 1. This dyke emerges from the sea at Benwee Head, in Erris, where it has occasioned a slip in the cliff; and the laminæ of the quartz rock are much curved and disturbed. A cavern passing through a point of the headland, and practicable by boats in calm weather only, has been formed by the decay of a portion of the dyke. Opposite the rock called Calliagh, a branch of the dyke appears as a mass of trap, enveloped in curved laminæ of the including rock. Further eastward, at Doonminulla, its disintegration has produced two caves, near which the strata are highly inclined, and the trap is conformably interleaved. Crossing thence the inlet of Portacloy, it rises vertically through the point of Attatovick, the strata of which are heaved up and bent over projecting portions of trap, like doubled folds of cloth, in the manner represented in the cut No. 3. From this point it passes under the sea to Pig Island, which it penetrates, presenting in the lower part, a pervious cavern, formed by its decay, and in the upper the appearance of a wall regularly built from shore to shore. This dyke does not intersect the coast again till it passes through Downpatrick Head, where it resembles a massive facing of polygonal prisms, raised against the cliff on each side of the point. I have not traced it further.

No. 2. The next dyke, to the southward, first appears in an inlet called Preeson, near Kid Island, traversing the quartz rock vertically for one fourth of its height, and then turning off horizontally in waved and irregular veins to the north and south, seems to have lifted the strata and penetrated between them. At Porturlin inlet, it forms a regular wall, piercing the precipice on the west side from the water's edge to the summit, and so closely resembles a fence of masonry, that a careless observer might be deceived. Crossing the entrance of the creek, and traversing the eastern point, it passes beneath the sea to Benmore Head, where it rises in the face of the cliff to half its height, and then ranges horizontally for some distance, terminating at last in a wedge. It appears also in the channel which separates Horse Island from the mainland, and can be most satisfactorily examined at low water, leaning against the quartz rock at the east end of the strait. A cave is there pervious to some distance, the roof presenting a very acutely pointed arch, and the passage between the Island and the main resulted probably, from the disintegration of the strata, altered by the trap. A vertical cross vein of wacké intersects it at an angle of 70°, having at the west side a thick wall of white quartz, in many places tinged green with oxide of copper, and a few yards from this cross vein, are two small parallel dykes of trap, containing zeolite. The stratification of the island is very much disturbed, and the derangement extends to the mainland, where the strata, in the next point in Balderig inlet, are elevated at an angle increasing from 70° next the sea, to 90°. On the eastern side, this dyke inclines to the south, underlying the strata of quartz rock, with which it would appear to be interstratified, and a prolongation has been thrown out in the form of a dyke, but it cannot be traced far.

The very extraordinary channel separating Illaan Maister from the extremity of Benmore Head, has been produced also by the removal of a branch of this dyke; its disintegration having left a chasm barely sufficient for a boat to row between its perpendicular and perfectly plane walls, 700 feet high. This pass is nearly dark in the middle, but of great grandeur and singularity, and accessible only in the calmest weather.

In the cliffs to the west of Horse Island are many fantastic and inexplicable appearances. The dyke, rising through the beds of rock, cuts them obliquely, and sends out, at one side, a regular stratum lying conformably between the layers of quartz rock. Near this, a mass of trap, incumbent on the edges of the quartz strata, which are perpendicular, penetrates between them like a series of wedges;—the vertical layers of rock, at one side of an upright vein of trap, are perfectly regular and parallel, while at the other side they are much waved and contorted;—masses

of the whin also occur, imbedded in undisturbed and regularly stratified rock, without an appearance of fracture, though of the most extraordinary shapes.

At Port Conoghrea the intermediate rocks commence, but their inclination and position are much disturbed by the vein, which passes thence to the south of Downpatrick Head; where it is seen to great advantage, forming an immense wall which lines the cliff from the water's edge, and is constituted of polygonal prisms closely fitted, transversly across the dyke, their ends forming the face of the wall. On the west (east?) side of the headland it is cut through by a cross vein of coarser trap, ranging north-west; but apparently no changes have been produced by this interference. On the east shore of Killalla Bay, the dyke is again found near the point of Kenisharrock, and afterwards in the cliff at Killeenduff, rising vertically from the water's edge. Further east it appears at both sides of Aghris Head, and proceeds to the sandbanks of Strandhill, which probably cover it. I have not sought it further.

The course thus detailed is forty-five English miles; and to view the dyke satisfactorily, at least half this distance must be passed in a boat, as closely as possible beneath the cliffs.

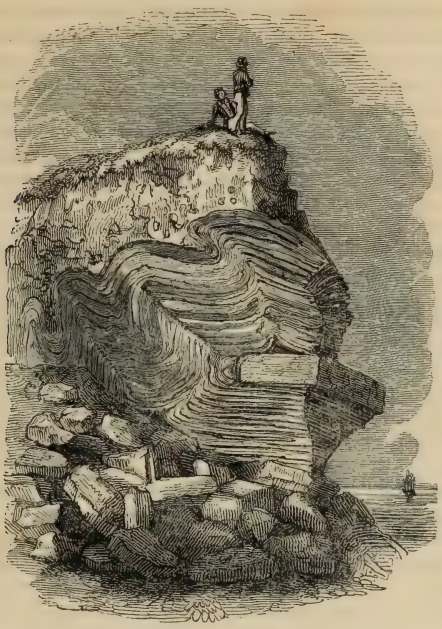
No. 3. Parallel to No. 2, and about two miles to the south, the third dyke emerges from the sea, near the south end of Rinroe Point, in Broad Haven, and extends by the foot of Knock-na-Ree, north of Ballisadere Bay, to Dromahair, in the county Leitrim (and probably further), a distance of about sixty-five English miles, while its breadth seldom exceeds forty feet. At Rinroe, the adjacent mica slate is considerably altered, all schistose structure having been obliterated, and the rock rendered loose and easily broken into irregularly angular fragments. It rises like a mole or pier from the water's edge, and this resemblance is rendered more striking, by the contiguous schist having yielded to the surge for some feet at each side, leaving a narrow and deep channel, up which the sea rushes. At forty yards distance is a parallel vein, but much smaller. Both veins cross the harbour, and appear on the east side at the water's edge.

These dykes have been traced across Ballinglan, and at Poolagranny, near Kilcummin Head, they are beautifully displayed, the northern being ten feet wide, and the southern about twenty. Passing through the alternating strata of sandstone, slate clay, and coarse limestone, they have given the shale a conchoidal fracture, prismatic structure, and black colour, in short converted it into flinty slate; the sandstone has been altered also, being partially translucent, much rifted, and in prismatic masses at the point of junction. These changes having rendered the strata exceedingly destructible, the surge has broken them up in the neighbourhood of the trap, and the dykes remain like ramparts of cyclopean masonry. At the east side of the creek, the beds of shale or slate clay mouldering away, have formed a cave or recess of some depth, bounded on one side by the trap vein, and on the other by the less decayed strata; the roof and sides of the cavity being covered by calcareous tufa, which frequently accompanies, and indeed often indicates the presence of trap. Over the entrance, a constant dropping of water has formed a sort of curtain or screen. The trap is here of a very coarse grain, and blackish green colour, the basis seems to be hornblende, with a sparing mixture of felspar, and is thickly studded with zeolite, in spherical concretions, and sometimes contains small nodules of green earth.

The passage of these trap dykes through both inferior and intermediate rocks, proves, that the fissures which they fill, could not have resulted from the contraction of the strata in drying or consolidating; the same cause having divided the quartz rock and mica slate, which, according to this theory, must have been firm and solid before the deposition of the shale, sandstone, and calcareous beds. In the banks which rise over the creek of Poolagranny, the upper beds of sandstone are much curved, with joints open above, in the convex part of the curve, and below where it is concave, while

the beds beneath remain horizontal. This derangement, therefore, can have resulted only from a lateral pressure forcing the layers of stone horizontally, but acting superficially. Such is the appearance exhibited in the hill north of Poolaclogher, on the east of Kilcummin headland, especially at a point near the landing place, represented in the accompanying wood-cut, No. 4.

No. 4.



Contorted strata of shale and grit north of Poolaclogher.

At Poolaheny, on the east side of Killalla Bay, the course of this dyke is often obscured by the drifting of a shingle-beach, but it is found to the east of the mouth of the Dromore River, on the coast of Tyreragh, preserving the same characters, and influencing the adjacent rock in the same manner. Thence, holding its direct course to the south-west of Aghris Head, and rising from the water through the beds of rock covered at high tide, it is seen for about 200 yards, but on reaching the shore, the sand banks and soil prevent further observation; and the dyke is concealed to the picturesque chasm, called the Glen, produced by it in the side of Knock-na-Ree.

The soil and the fallen rocks which have been thrown together and levelled to form a walk through "the Glen," obscure the trap except at a few points, where it may be examined satisfactorily. To judge from the present appearance of the rift, it was never filled to the brink with trap; as the sides would close together with scarcely any void, the projections of one face coinciding accurately with the recesses of the other. I have next observed this dyke below the village of

Dromahair, in the county Leitrim, running parallel to the river, which falls into the east end of Lough Gill; and here an unusual change occurs, the material of the vein consisting of vertical layers of serpentine. The mica slate, when in contact with the vein, presents a bright red colour, and crumbles between the fingers, as if it had been intensely heated; and veins of asbestos occur abundantly in the dyke between the coarse laminæ which compose it. The schist rises towards the vein at each side, as if it had been elevated by a force from below, and the serpentine forms a narrow line of hill along the river, where its stream turns to the eastward, opposite Friarstown, about half a mile from the town. I have not traced it further, but there is no appearance of a termination.

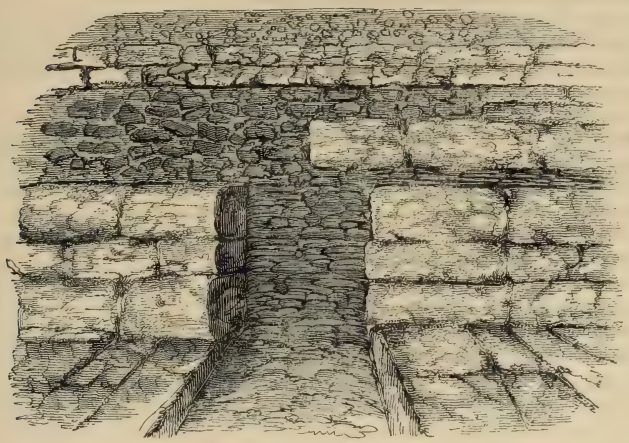
No. 4. This dyke is found in the west side of Erris Head, where a pigeon hole (as those caverns in the cliffs, with an opening in the roof are called) has resulted from its disintegration. It appears again at the opposite side, rising from the water's edge to the summit of the precipice; and it crosses Broad Haven, but the drifting sands at the mouth of the Glanamoy River conceal its course, as do the bog and moor to the valley of Ballinglan. At the last locality, the shale and grit beds are much deranged by its influence, the shale being indurated and converted into a black quartzy chert, rifted most irregularly, and the crevices are filled with quartz, highly crystalline, and shooting into hexagonal pyramids; and the layers of grit are disturbed and fissured. It is prolonged thence to Kilcummin, appearing in the road on the west side; and traversing the head it is seen among the rocks on the sea shore, near Castlemagee. It is there porphyritic, being chiefly composed of large tabular concretions of felspar, and contains augit and green earth. On the east shore of Killalla Bay, it passes through the limestone, and may be observed further east, at Conquil Bridge, and is well displayed at Dromore West, having there raised up the limestone at each side, altered the colour, and rendered the structure more granular. It constitutes the fall in the river close to the bridge; beyond which the stream runs in a deep ravine, caused by the decomposition of the limestone, but the dyke lines one side of the bank some distance below. It has been observed by Mr. J. Wynne, of Hazlewood, at Dromiskeybole, near the west end of Lough Gill; and in the pass through Slish Mountain, close to the Ballintogher road, it either sends a branch to the north-west, or is crossed by another dyke. I have, as yet, been unable to determine this point, but a ridge of serpentine is found there, near and parallel to the road, for the repair of which it furnishes the material. There is almost an identity between specimens from this site and those from the Dromahair dyke; they are both laminated, both contain asbestos, and agree in colour and hardness. My examination terminated here.

No. 5. This dyke first appears as a singular and picturesque narrow stair-case of prisms, ascending from the sea between two high walls of indurated mica slate, almost porcelainised by its contact, and the schistose structure is obliterated. The steps consist of short columns, lying horizontally across the vein, from side to side. Penetrating the peninsula of Erris, and crossing, eastward of Broad Haven, the district of Kilcommon, the peat and soil conceal its course, till it appears in Ballinglan, where it can be traced up a ravine through which a stream flows from the moory summit of Knock Aghleeg; and on the east side of that hill, it crosses the stream of Carrickanass, traversing the beds of sandstone without any apparent effect. It continues thence by Rafron and Ross to the Bay of Killalla, passing for some distance through the bed of trachyte, where it assumes the appearance of basalt, black, fine-grained and prismatic, in one place regularly columnar, and the pillars are as neatly defined as those of the Giants' Causeway, but their axes are nearly horizontal, being at right angles to the walls of the vein. In Palmerstown River it appears like three walls of polygonal prisms, built in contact with each other; and the surrounding rock having been decomposed and washed away, its construction is laid open. The prisms where weathered, peel off

easily in concentric layers, but they increase in hardness as the interior is approached, where they are extremely tough and refractory.

The appearance of this fifth dyke, on the east shore of Killalla Bay, is attended with peculiar and instructive circumstances (see the accompanying wood-cut, No. 5.). Rising through the carboniferous limestone, it destroys the colour as usual, but about four feet from the surface the limestone strata above the dyke are much shaken and disturbed, and the trap has turned off laterally beneath this disturbed mass, and divided into small nodules, cemented together by calcareous spar, thus forming a conglomerate. A careful examination has convinced me that the trap, on reaching the point where its ascent ceased, became mingled with fused limestone, the carbonic acid of which was separating abundantly from the diminution of pressure. The conglomerate could not have been produced by infiltration, because the cement occupies more space than the nodules enveloped by it, which are not in contact. The further course of this dyke has not been observed.

No. 5.



Trap dyke in carboniferous limestone east side of Killalla Bay.

No. 6, the next dyke in succession, commences at the sea, near the vicarage of Tarmoncarra, in Erris, and has caused one of those caverns, called Pigeon-holes. From its direction, this dyke may probably be identified with that which appears opposite to the mill of Tully, above the bridge, on the Palmerstown river, penetrating the sandstone strata, a few yards from their junction with the overlying limestone; and is seen again at the coast guard boat harbour at Enniscrone, on the east side of Killalla Bay. It is there twenty feet wide, and has rendered the limestone white and compact for several yards at each side, but the calcareous strata gradually resume their usual dark grey colour. I have not searched for the continuation of this vein.

No. 7. dyke begins in mica slate at Annagh in Erris, and crosses to Bel Mullet, where it is found on the shore a little north of the town. It reappears in the new road to Ballinglan, south-west of Killalla Bay, and afterwards in the inlet below Moyne Abbey, where are five parallel branches

which have produced much derangement in the rock, and apparently contributed to the subsidence in the neighbourhood of Killalla, from the mouth of the river Moy to the bridge at Palmerstown. The abrupt façade of oolitic limestone, from near Moyne by Kilroe to Castlerea, appears to be a portion of the undisturbed stratum, while the broken and sunken beds of rock which skirt the shore, and the depression which is covered by the tide within the Island of Bartra, seem the result of a subsidence. One of the veins of trap below Moyne differs in composition, containing calcareous spar and olivin, and breaking with a compact fracture, while the others are externally decomposed, very friable, and abound with small concretions of zeolite.

No. 8. The point where this dyke might probably first be seen in Erris, is covered by drift sand, but on the south shore of Broad Haven, below the road near Derracorib, it has tilted the strata into a vertical position. It is well seen near the Glebe House at Mullafarry, south of Killalla Bay, where it consists of concentrically foliated spheroids, weathering in successive coats, and surrounding a very tough, crystalline nucleus. The limestone, as usual, is white, friable, and earthy near the dyke. This vein was exposed near Annaghmore, during an alteration in the road at Ardcree Bridge. Its possible range further east will be alluded to hereafter.

No. 9. dyke is seen near Ballybroony, south of Killalla Bay, and crossing the Moy, traverses the glebe land of Killanly. The limestone is converted by the dyke into a calcareous breccia of angular fragments cemented by calcareous spar, as if heat had rifted and cracked the rock, among the fragments of which, fused limestone had been then injected.

No 10. crosses the valley of Glencastle in Erris, near the eastern end of the bridge, the parapet of which abuts on the vein. It penetrates the mica slate, and the beds are much waved and contorted as the dyke is approached; but at the meeting of the trap and schist, the latter is decomposed to a ferruginous clay: the dip also is altered from about 45° north-west to 80° north. It contains quartz veins abundantly. It is seen again along the side of the road near Netley Park, and crosses the river Moy near Bunree, the marl or calcareous tuff indicating its presence; it is also visible in the mail-coach road to Dromore.

No. 11. This dyke traverses the peninsula of Erris, appearing on both the west and east shores, and produces considerable alteration in the hornblende rock at Leam, which is rendered so nearly identical with the trap, that it is difficult to distinguish the exact boundary. A dyke is seen on the right bank of the Moy, about a mile from Ballina, on the road to Dromore, and probably is the continuation of this.

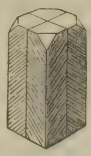
I have not sought for dykes to the southward of Ballina, but I think it very likely that many may be found; I have heard that one is visible near Castlebar.

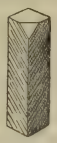
K. *The Trachyte Formation.*

I have not seen any notice of the occurrence of this rock in the British Islands; but the use of the term has been sanctioned by the authority of Mr. Poulett Scrope, as applied to the formation in question; and I take this opportunity of acknowledging the kind aid of his opinion. It is found in Ross, north of Killalla. On tracing the coast southward from the mouth of Palmerstown River, a bold sandstone rock rises suddenly from the beach in irregular but level strata, which, however, soon dip to the south in a confused and fractured state, and are followed by a mass of trachyte composed of glassy felspar in irregularly quadrangular tables, mingled with black augit in laminar concre-

tions, the plates of which are generally parallel, reflecting the light at the same angle over the surface of the specimen. Quartz in hexagonal pyramids also occurs, as well as green earth, lepidolite, and different zeolites. Near the middle of the mass, which is about 1100 yards wide, the felspar becomes opaque, yellowish grey, and regularly crystallized in rectangular prisms, the augite diminishing in quantity, and the zeolites and quartz increasing; but on approaching the southern boundary the augite predominates, and the felspar resumes its transparency and greyish colour. Near the limits of the mass, changes gradually take place, the grain becoming closer, and the crystals diminishing in size, till the trachyte can scarcely be distinguished from the sandstone. The latter rock also becomes more compact and harder at the junction, while the shale passes into Lydian stone, and the stratification is much deranged, the dip being towards the trachyte on both the north and south limits. A small dyke or vein is seen at the southern part of this bed, having nearly an east direction. A few yards from the point where it emerges from the bank, it is broken across and discontinued, but about three feet to the south, occurs again in the same direction. This lateral shift or removal, is twice repeated before it reaches low-water mark, and suggests the idea of successive horizontal slips having taken place, from the north, after the consolidation of this vein and the including rock. The trachyte is continued across the lands of Ross to the Palmerstown River, where it forms the bank for some distance, and its junction with the sandstone is well displayed under the old church of Templemary on the opposite shore. Having been protruded laterally, it lies above, and at the plane of contact a substance is interposed resembling fine clay slate, except in the lamellar structure. Could this intervening layer have proceeded from fusion of the sandstone alone, or from its component parts mingling with those of the liquid trachyte in the proportions which form clay slate? Analysis might determine the question. Augite here predominates, and the rock graduates into a coarse basalt in jointed columns. Ascending to the cross-roads at Mullinacrush, the bed approaches more to porphyry, being almost entirely composed of glassy felspar in thin tabular crystals laterally compacted together, and in detached portions presenting a schistose aspect, but in the mass rising in blocks like granite, without any approach to stratification. It contains very sparingly, zeolite, chalcedony, iron pyrites, and augite. It occupies the summit of the hill, not, however, extending far to the westward. On the opposite shore of Killalla Bay, I found the trachyte on the lands of Cahirvove, bounded by limestone, upon which it appears to lie; but no seam divides the two rocks, which are mingled irregularly at their junction, the limestone containing both felspar and

augite. At this side the character of the bed differs slightly from that of Ross, being more varied in structure, and might be applied to ornamental purposes, if not too hard to be wrought satisfactorily. The felspar, which occurs abundantly at Ross, presents unusual varieties in the crystallization. The crystals appear to be rectangular prisms, having the terminal angles replaced by triangular planes; but on close inspection they are found to consist of two or four prisms attached laterally. Striæ may be seen with a magnifier on the planes parallel to the edges of that replacing the angle of the prism; and as these striæ diverge from the line of junction, the crystal has a feathered appearance, as represented in the wood-cuts. The conditions under which the complicated arrangement of the ultimate particles, and of the simple and compound crystals were effected, apparently indicate perfect tranquillity, complete fusion, and very slow cooling of the mass. This conjecture is supported by the fact, that the most perfect crystals are found about the centre of the bed, the part which would longest retain its heat and fluidity.





The occurrence of trachyte (a formation hitherto unobserved in the British Islands) at the shores of the bay of Killalla, is an interesting discovery. Of the period when the rock was formed, it can only be said with certainty, that it is newer than the mountain limestone, and older than the system of trap dykes, as it lies on the former, and is penetrated by No. 5, one of the latter.

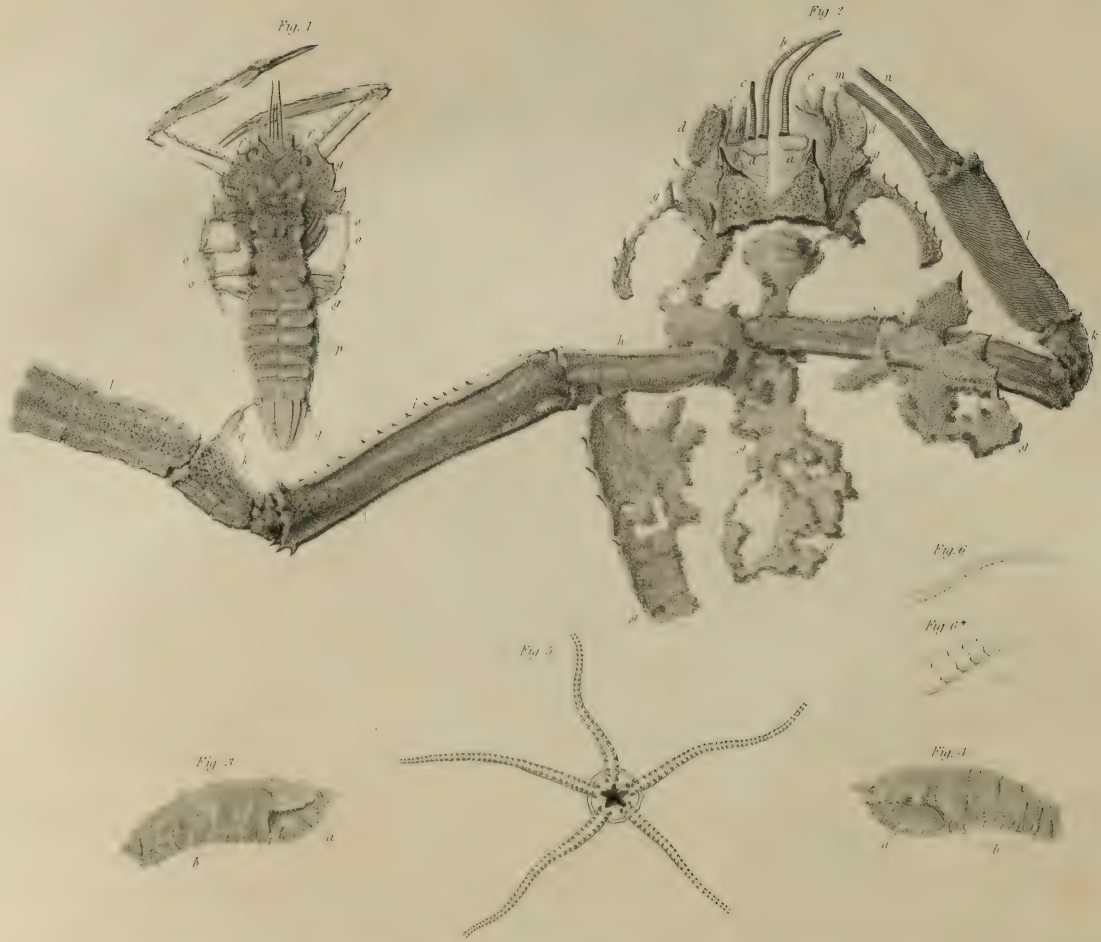


Fig. 1
Fig. 2
Fig. 3
Fig. 4
Fig. 5
Fig. 6
Fig. 6*

XII.—*Description of some Fossil Crustacea and Radiata, found at Lyme Regis, in Dorsetshire.*

By W. J. BRODERIP, Esq., F.G.S., F.R.S., &c., V.P.Z.S.

[Read June 10, 1835.]

LORD COLE and Sir Philip Egerton having placed in my hands some fossils, which they have lately found at Lyme Regis, I proceed to describe those which appear to me to be new. (See Plate XII.)

1. Crustacea.

The first of this class to which I shall call attention is a crustacean, which must have been of considerable size, and which, from its form, appears to me to be very interesting. Though the *post-abdomen*, or tail, as it is vernacularly called, is entirely wanting, enough remains of the anterior parts to indicate in a satisfactory manner the organization of the animal, and its place among its congeners. The lamellæ of the external antennæ would show that it was a macrourous decapod, of the Shrimp family (*Salicoques* of the French), and the chelæ have some characters approaching to those of Palæmon; but the absence of the serrated rostrum and the presence of other characters forbid us to arrange it under that genus. The middle notch of the carapace, and indeed the general form of that part are very like Palinurus. If the habits of this animal may be considered to have approached those of the Shrimps (and the very thin armour of the carapace would lead a good way to this conclusion), its remains are those of a comparative giant of that race, fit to grapple with the decomposing flesh of the Enaliosaurians. Upon the whole evidence the place of this animal appears to me to be between Palinurus and the Shrimps, and its organization leads me to consider it as a crustacean *sui generis**. I have named it in honour of Lord Cole, whose zeal in

* M. Milne Edwards, in his *Histoire Naturelle des Crustacés* (tom. ii. p. 337.), gives the characters from my description in the "Proceedings," and says, "Le Genre Coleia, établi récemment par M. Broderip, d'après un Crustacé fossile du Lias, n'est aussi qu'imparfaitement connu, mais nous paraît devoir être intermédiaire entre les Astaciens et les Salicoques;" and he, accordingly, places it between *Nephrops* and *Crangon*. When M. Milne Edwards wrote, the smaller but more perfect specimen with the post-abdominal segments was not known to me, nor were

collecting is only equalled by the liberality with which he applies the riches of his museum to the advancement of science.

Since the above was written, Mr. Lonsdale forwarded to me another specimen from Lyme, which upon examination turned out to be a young individual of the same species, having the post-abdomen or tail *in situ*, and the other parts comparatively perfect. This specimen, which is in the Museum of the Geological Society, so entirely corroborates the view which I had formed from the examination of Lord Cole's large specimen, that I have only found it necessary to add the description of the post-abdominal segments*.

Coleia.

Generic Character.

Antennæ. Base of Mesial antennæ (antennæ internæ) not extending beyond the anterior spine of the thorax; each antenna terminated by two annular setæ, the external setæ being the longest. External antennæ provided with a large and wide scale; the terminal setæ large, but the length undetermined.

Eyes, pedunculated, directed outwards, approaching in their situation and form to those of Palinurus.

Thorax (carapace), thin, divided transversely by furrows indicating the different regions, tuberculated, spinous at the sides, and with three deep emarginations anteriorly, the middle one the largest, each of the four anterior angles produced into a strong spine.

Feet. First pair long, slender, the *cubit* (cubitus) with small spines or serrations on the internal margin, and terminated externally by three strong spines. *Hand* (manus) elongated, slender; *digits* slightly incurved, filiform, unarmed, pointed.

Post-abdominal segments, tuberculated and strongly marked by transverse ridges. Caudal lamellæ approaching in their form to those of the salicoques or shrimps.

Species. Coleia antiqua.

Mus. Cole. Pl. XII. fig. 1, 2.

Found in the lias at Lyme Regis by Miss Anning.

I have next to notice a fragment of the post-abdomen of another macrourous decapod, approaching in its sculpture nearest to Palinurus. This crus-

either of the figures which now illustrate this part of the paper published. M. Milne Edwards in giving the description seems to think that the *carpus*, not the *cubitus*, was intended by the author, when he describes the joint as having small spines or serratures on the internal margin, and as being terminated by three strong spines; for M. Edwards writes, "le cubitus (Carpe?) garni de petites épines," etc. It is the cubitus that is so armed. (Sept., 1837.)

* This interesting specimen was the property of Alfred Cloyne Austen, Esq., F.G.S., who left it with Mr. Lonsdale to be described. When Mr. Lonsdale informed him that it was introduced into the plate illustrating this little memoir, he most liberally presented it to the Geological Society.

tacean must have been of large size, as large as that of the common Palinurus (sea crawfish of the shops)*. From the lias.

A series of specimens next claims our attention; but the state in which they are renders it difficult to lay down any generic character. The remains are those of another macrourous decapod of a rather small size. The chelæ and legs are washed away, and the carapace is very obscure. Two of the specimens however present a curious phænomenon. In these the accurate observer will see the breathing organs of this delicate crustacean, after an inhumation of thousands of years, presented to him in a petrified state. The tips of the four larger branchiæ, and of the four smaller ones below, may be observed pointing towards the situation of the heart, and these branchiæ show that the crustacean before us did not belong to the Amphipoda, but to the highest division of the Macroura. The spines are like those of *Crangon salebrosus;* and the general organization, so far as it is presented to our view, reminds us of the arctic forms of the Macroura. I am aware that the information afforded by these specimens, though it is of a highly interesting nature, is only scanty; but there is enough to satisfy me, and indeed to convince my friend Mr. Owen, whose attention to this branch of natural history makes his opinion of great value, that these crustaceans evidently belonged to the salicoques of Latreille. I am inclined to think that two of the specimens are specifically different from the others, and in one a monodactylous leg is preserved. Two of those which afford the best information on the subject of the petrified branchiæ are figured Pl. XII. fig. 3, 4.

These crustaceans were found immediately below the town of Lyme, on *Broad-ledge*, which consists of a bed of finely laminated lias shale. They were associated with Pholidophori, viz. *Bechei, latiusculus* and *medius;* and also with several species of Tetragonolepis and Dapedium, and with remains of Ichthyosaurus and Plesiosaurus.

2. Radiata.

Genus Ophiura.

The specimens of this Ophiura, which I believe to be undescribed, were found about half a mile west of Bridport Harbour, in masses of micaceous sandstone which had fallen from the cliff to the beach. (See Mr. de la Beche's section, Trans. Geol. Soc. vol. ii. pl. III. 2d series.) Mr. Lonsdale considers

* The figure of the imperfect remains of a crustaceous animal, from the cabinet of Miss Philpot of Lyme (Trans. Geol. Soc. vol. iv. Pl. II. 2d series), does not afford sufficient information for accurate comparison.

the bed to be a member of the lias, between the alum shale of Yorkshire, and the lias of the west of England. He considers the lower part of the sand, represented in Mr. de la Beche's section, to be the marlstone of William Smith; and the bed of grey marl to be the representative of the alum shale of Yorkshire.

Ophiura Egertoni.

Oph. radiis tereti-subulatis, articulis supernè subtrilobatis, disco sub-plano, subpentagono, rotundato*.

Mus. Cole.—Egerton. Pl. XII. fig. 5, 6, 6*.

This species approaches very near to *Ophiura texturata*, nor is it at all improbable that the living Ophiura may sometimes rest on the remains of its ancient fossil congener; for Lord Cole and Sir Philip Egerton dredged up the recent animal from the trawling ground at Lyme.

Some of the specimens have been weathered to a nicety, and these display in a beautiful manner the articulation and structure of the animal. Others are surrounded and clogged with the matrix, and this is only noticed that the different appearances may not lead to a supposition that there is among them more than one species, viz., that which I have named after the indefatigable Sir Philip Egerton, who worked the specimens out with his own hand. Since the above was written Lord Cole has found some very small individuals.

Ophiura Egertoni differs from *Ophiura Milleri* of Professor J. Phillips, inasmuch as, among other differences, the disk of the latter is lobated, according to the figure given in the "Geology of the Yorkshire coast," Plate XIII. fig. 20. There is no description; but there is authority for considering the figure to be correct, though it is stated to have been drawn from separate parts†.

Genus Cidaris.

Several specimens of this genus are among the collection submitted to my observation. They appear to me to be the same species in different stages of growth, and may be identical with that figured as an Echinus by Mr. de la Beche, in the Trans. Geol. Soc. vol. ii. Pl. IV., 2d series. I have not seen the specimen, but the proportion of the mamilla, or ball of the spine joint, as given in the figure, is larger than that of the same part in those before me.

Cidaris Bechei.

Cid. testâ subglobosâ, mamillis parvulis, spinis elongatis, aculeatis.

Mus. Cole.—Egerton.

I have named this cidaris after my friend Mr. de la Beche, whose geological works are too extensively known and valued, to require more than an allusion to them on my part.

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* The reader must remember that the external surface is abraded, in the specimen from which the description and principal figure are taken; and that in its natural state, the disk had probably a more rounded form.

† I have not been able to procure a sight of the fossil Ophiura, in the museum of Mr. Matthew Wright of Bristol, from the lias on the banks of the Severn in Gloucestershire, and the cast does not convey sufficient information for comparison. Professor Sedgwick has been good enough to forward to me three specimens of Ophiura, which he had procured from Miss Anning. They appear to me to be all *Ophiuræ Egertoni*.

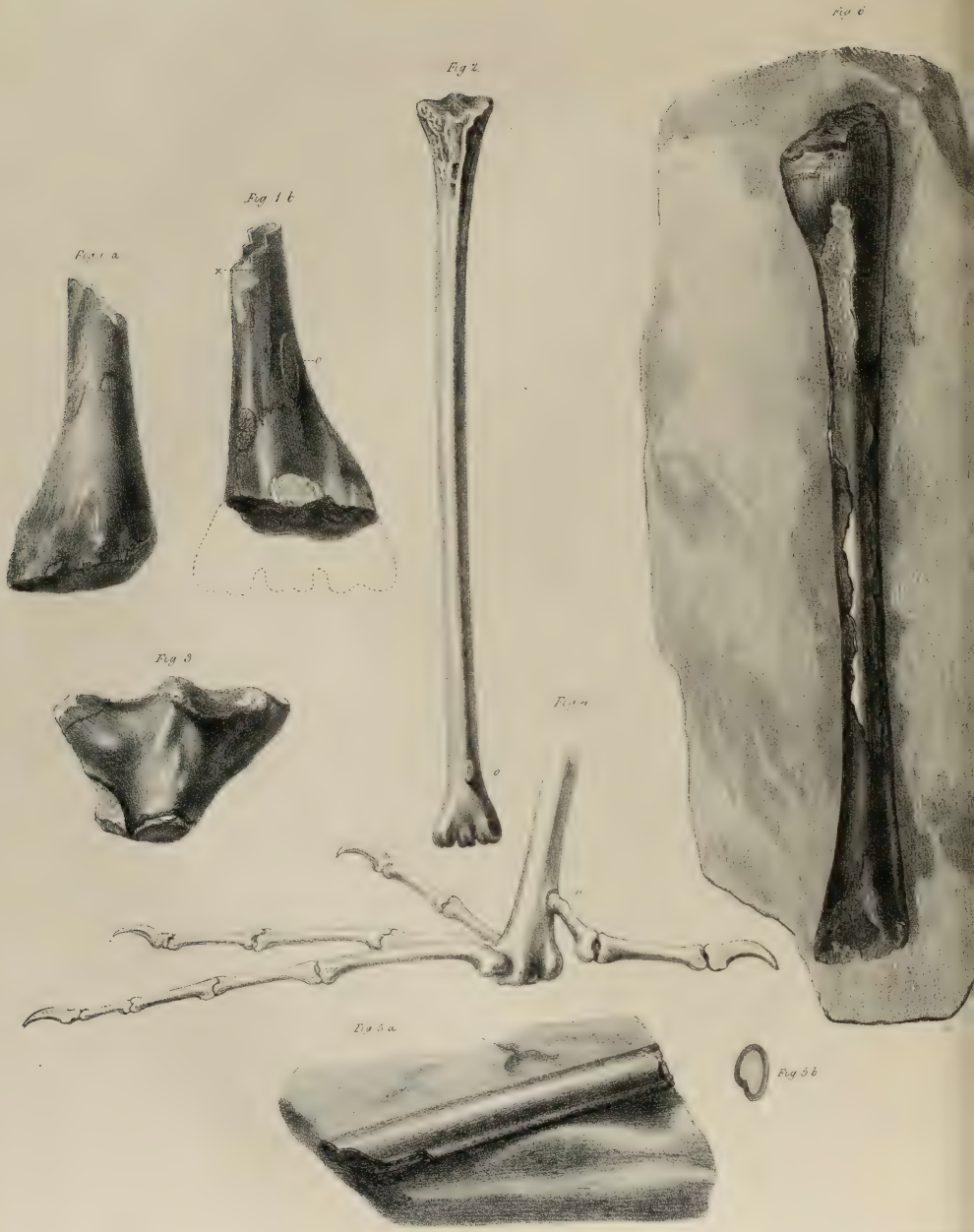


Fig 1 a & b Tarso-metatarsal bone of a fossil bird p. 177.
3, 5 and 6 Fossil bird's bones p 177
Found in the strata of Tilgate Forest

Fig 2 Tarso-metatarsal of the Heron
(Ardea cinerea)
4 Distal extremity of the Tarso-metatarsal

XIII.—*On the Bones of Birds discovered in the Strata of Tilgate Forest, in Sussex.*

By GIDEON MANTELL, Esq., L.L.D., F.R.S., &c.

[Read June 10, 1835.]

THE remains of birds are so seldom found in a fossil state, that a notice of unquestionable relics of this class of animals, however imperfect, cannot fail to be interesting to the geologist and comparative anatomist. Mr. Lyell has well remarked in his Principles of Geology*, that it might readily have been anticipated, that the fossil bones of birds would be of rare occurrence, since the power of flight possessed by these animals, preserves them from many casualties by which quadrupeds are destroyed and imbedded; and that even when birds are drowned, or chance to die on the water, the tubular structure of their bones, and their feathery coverings, would generally occasion them to float on the surface, until their carcases were devoured. We find, accordingly, but very few authenticated examples of fossil birds, certainly none (with the exception of those which it is my present purpose to describe) that can be referred to strata of an earlier period than the gypsum beds of the Paris basin†. It is true that the thin fragile bones which occur in the slate of Stonesfield were formerly assigned to birds‡, but all these are now known to belong to Pterodactyles.

Soon after my attention was first directed to the fossils of the Wealden of the south-east of England, I discovered in the strata of Tilgate Forest, several bones of such extreme tenuity as could have been required only by animals intended for flight, and some of these, from their close resemblance to the tarso-metatarsal bones of certain *Grallæ* or waders, I was induced to refer to birds§. But when the correctness of the opinion of the late Mr. Miller, that the Stonesfield bones belonged to Pterodactyles, was established, it was naturally conjectured, that the fossils from Tilgate Forest might also have been derived from flying reptiles; and Dr. Buckland expressed a doubt

* Principles of Geology, 5th edition, vol. iii. p. 230.

† Oss. Foss., 5me edit. tom. iii. p. 303. ‡ Geology of England and Wales, p. 208.

§ Geology of Sussex, 1822. Fossils of Tilgate Forest, 1827.

"whether there were any certain evidence of the existence of fossil birds in strata more ancient than the tertiary*." Having subsequently discovered a few specimens with more decided characters, I was led to resume my former opinion, the accuracy of which was confirmed by M. Cuvier, during his last visit to England, who pronounced, without the least hesitation, that the specimens were the bones of some wader, probably a species of *Ardea*, or heron. Yet, notwithstanding this high authority, the imperfect state of the specimens induced some eminent naturalists to regard the question as still undetermined; their scepticism however will, I trust, be now removed, by the recent discovery of a bone, which, as will hereafter be shown, can be no other than the tarso-metatarsal of a bird.

A short time since, my friend Mr. Lyell and myself, being engaged in some investigations relating to the fossil bones of turtles, the supposed birds' bones of the Wealden again came under our notice; and as the subject was of deep interest, the presumed existence of birds during the period of the secondary formations, resting solely on the evidence afforded by the specimens in my collection, we determined to submit the most characteristic bones to the examination of Mr. Richard Owen, of the Royal College of Surgeons, a gentleman whose profound knowledge of comparative anatomy, is only equalled by the liberality with which he imparts his valuable information to others. Mr. Owen's attention was first requested to the metatarsal bone above mentioned, and particularly directed to the oval cicatrix (*o*, fig. 1. *b*, pl. XIII.) and the longitudinal ridge (×, fig. 1. *b*) observable in that specimen, both of which are very peculiar characters. The following observations are the result of Mr. Owen's examination:

"This fragment (fig. 1. *b*) is undoubtedly the distal extremity of a left tarso-metatarsal bone of a bird. The oval spot (*o*,) denotes the articular surface or place of attachment of the posterior or opposable toe, and is a mark of more than ordinary importance, since much may be deduced of the habits of the bird by observing its relative situation to the articular surfaces of the other toes. Thus, in an insessorial, or climbing bird, it is placed nearly on a level with the others, that the back toe may be effectually opposed to the fore toes; and the same obtains in the raptorial birds for seizing their prey. I infer that your specimen belonged to a wader, and that the back toe was a long one, the better adapted for supporting the body on a marshy soil. The thin longitudinal ridges of bone in the fossil, also agree with what may be observed in the metatarsals of birds; they afford attachment to the aponeurotic thecæ, which tie down the tendons as they glide along the metatarsus to the toes. As the soft articular extremity of the bone has been destroyed, it is probable the bird was young, and the epiphysis not anchylosed. Another of the specimens is very like the head of a humerus of a bird, but differs from any in the museum

* Geol. Trans., 2nd series, vol. iii. p. 220.

of the College, in the sudden expansion of the head. Fig. 3 appears to be the proximal end of a tibia. In others of the long bones from the Tilgate strata, there are longitudinal grooves which accord with what is observable in the metatarsal bones of birds, but similar grooves appear also to characterise most of the long bones of Pterodactyles. However, the metatarsal bone (fig. 1, *a*, *b*,) settles the question in my mind as to the existence of the remains of birds in the strata of Tilgate Forest."

The confirmation of my opinion, first by the immortal Cuvier, and now after a rigorous examination of other specimens, by Mr. Owen, must I conceive remove all doubts on the subject, and the occurrence of the remains of birds in strata antecedent to the chalk, be henceforth considered as unquestionably established as that of mammalia in the Stonesfield slate.

I proceed to describe the specimens of birds' bones in my possession; they are but few in number, and unfortunately all of them are more or less imperfect, the extreme thinness of the bones, and the compactness of the rock in which they are imbedded, rendering it impossible to extricate them without injury.

Tarso-metatarsal bone of a Wader, Pl. XIII. figs. 1, *a*, *b*.—This is the most important specimen hitherto found; it consists of the two extremities only, the shaft of the bone having been crushed, and a considerable portion of it, perhaps four or more inches, lost. Its circumference is three times that of the corresponding bone of a heron. The annexed sketches illustrate its most essential characters; the distal extremity, fig. 1, *b*. is represented on its posterior aspect: *o*, shows the oval depression for the articulation of the hind-toe, or thumb: ×, a ridge for the attachment of the aponeurosis of the tendinous sheath which embraces the tendons passing down to the foot: fig. 1, *a*, anterior view of the same specimen.

"*Tibia?* or *metatarsal.*" *Cuvier.* Pl. XIII. fig. 6.—A slender bone, six inches and a half in length, the head of which is partially exposed; the distal extremity is wanting. Fragments of similar bones are represented, Pl. VIII. figs. 1. 18. *Fossils of Tilgate Forest.*

Tibia? Pl. XIII. fig. 3.—The head of a tibia (?): this specimen is figured Pl. VIII. fig. 11. *Fossils of Tilgate Forest.*

Ulna.—I have two fragments of cylindrical bones, apparently portions of the ulna, each having a small tubercle, like that observable in birds for the attachment of the quills of the secondary feathers; but these specimens are too imperfect to warrant any positive inferences.

Such are the scanty materials from which I venture to infer the existence of birds during the Iguanodon epoch; and if my deductions be correct, another beautiful instance is afforded of the light shed by anatomical science on the obscure records of the early history of the earth.

XIV.—*On the Syenite Veins which traverse Mica Slate and Chalk at Goodland Cliff and Torr Eskert, to the south of Fair Head, in the County of Antrim.*

By RICHARD GRIFFITH, Esq., F.G.S., M.R.I.A., P.G.S. of Dublin, &c.

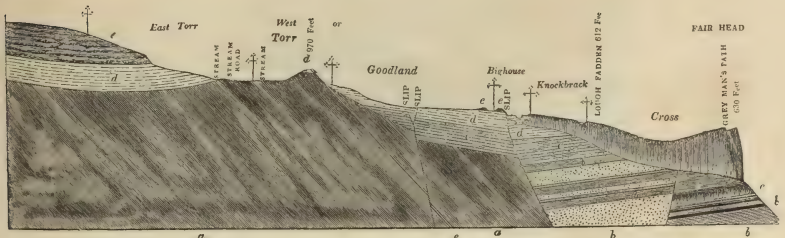
[Read January 6, 1836.]

THE geology of the northern portion of the county of Antrim, has been often treated of; but there are several interesting facts, which have apparently escaped the attention of preceding observers. One of the most important was described by me in the Geological Section at the late meeting of the British Association in Dublin; and I have since revisited the place, accompanied by my friends Professor Sedgwick and Mr. Murchison, at whose request I have prepared the following memoir for the Geological Society*.

The part of Antrim to which this paper refers, is situated between Fair Head, on the north, and Cushleake Mountain, on the south.

The geological structure of the country is exhibited in the accompanying section, No. 1. It will be seen, that mica slate forms the substratum or base

No. 1.



a, Mica slate; *b*, coal shale; *b* with dots, coal sandstone; *c*, new red sandstone; *d*, chalk; *e*, trap, or syenite.

of the country; that secondary rocks, belonging to the coal formation, the new red sandstone, and chalk rest upon it unconformably; and that these secondary rocks are surmounted by an overlying mass of rudely columnar

* These veins, together with that at Torr Eskert, were originally observed by Mr. Nicholson, one of the first class of valuators employed on the general valuation of Ireland.

trap, which at its northern extremity, forms the magnificent promontory, called Fair Head.

The mica slate is distinctly bedded, and passes from a fine-grained, shining, slaty rock, into a coarsely granular gneiss. Its subordinate strata are hornblende slate and schistose limestone; the latter occurring in several places, particularly on the sea shore, close to the south side of Torr Point, and on the shore at West Torr. At Goodland Cliff, near the northern extremity, the dip is north-west, at an angle of 15° from the horizon, and the subordinate beds of schistose limestone and hornblende slate dip conformably with the mica schist, and are consequently contemporaneous portions of it. Other rocks containing hornblende are, however, frequently associated with the mica slate, and though apparently imbedded with that rock, are veins which have been intruded, subsequently to its formation. This is particularly the case at Torr Point and other localities, one of the most remarkable of which is on the sea shore, half a mile to the south of the commencement of the mica slate in Murlough Bay, where are two decidedly intruded veins of syenite, which pass into syenitic greenstone. (See the following cut, No. 2.)

No. 2.

Syenite veins (*e*) passing through mica slate (*a*), in Goodland Cliff, south of Murlough Bay.

These veins pass obliquely through the mica slate, in the face of the stupendous cliff of Goodland, which is upwards of 500 feet high, and for the greater part nearly perpendicular. They are clearly visible along the face of the cliff for more than half a mile. At the sea shore, the veins appear to range so regularly and conformably with the strata of mica slate, both in strike and dip, that if not closely examined they might be considered subordinate beds; but on minute inspection, it will be found that the edges

are frequently rough and saw-like ; and that the projections are filled by syenite, continuous with the mass ; and the indentations in the veins with mica slate, having a tortuous structure.

On tracing these veins as they gradually ascend the cliff to the south-east, their true nature is at once discernible. There, they may be seen pursuing undulating courses, neither parallel to each other nor to the laminæ of the mica slate ; in some places approaching to within four feet, but in others, being more than twenty feet apart. (See cut, No. 2.)

About 150 yards to the south of the point, where the veins meet the surface of the ocean, and where the lowest has reached the height of about 120 feet, the cliff is fractured by a great fault, or downthrow of the strata to the north ; and by means of which the cliff is accessible. To the south of the fault, the veins are at about 100 feet higher level than to the north, and it is remarkable that to the south of this point *three* veins are observable, instead of two, by the introduction of a small vein, which, when first observed, is in contact with the upper surface of the lower vein, but gradually diverging from it, approaches the upper vein, and afterwards descends a second time towards the lower vein. The accompanying sectional view, No. 3, was taken a short distance to the south of the fault. At this place the upper vein is about five feet thick ; the middle is fourteen inches, and the lower about seven feet ; and the distance between the upper and lower veins is fourteen feet, including the middle vein.

No. 3.

Syenite veins (*e*) traversing mica slate (*a*) in Goodland Cliff, south of Murlough Bay.

The mass of the upper and lower veins is composed of dark green, crystallized hornblende, brownish red felspar, and occasionally quartz. The rock may be said to be finely grained. The hornblende is crystallized in long six-sided prisms; and the felspar exhibits its usual rhomboidal structure, but no distinct crystals. It is to be observed, that the hornblende is more abundant near the upper and lower parts of the vein than in the centre, and a regular transition between syenite and greenstone, is observable in the mass of the vein. This variation is most remarkable in the thin centre vein, which contains much black hornblende, and some black quartz. This vein is also peculiar from its presenting oval-shaped masses, from two to ten inches in diameter, and about one third as thick, composed of crystalline greenstone, enveloped in a congeries of plates of pinchbeck brown mica. In one or two places, I observed a tendency to similar structure in the upper vein.

When seen at a distance, the upper and lower veins present a rudely columnar structure, the prisms being at right angles to the inclination of the veins.

Syenite, similar in every respect to the upper and lower veins, occurs near to the summit of Torr Eskert Hill, about half a mile to the south of Goodland Cliff. (See wood-cut, No. 1. p. 179.)

Owing to the covering of diluvial matter, the surface soil, and herbage, it is impossible to trace the syenite veins of the coast to this point; but in laying down the line of the veins of Goodland Cliff on the Ordnance Map, and making due allowance for their average inclination, and the elevation of the hill, I entertain no doubt that the syenite of Torr Eskert, is a prolongation of one of the veins of the cliff.

Torr Eskert Hill is about 970 feet above the level of the sea. At a distance, it presents a bold escarpment to the north, and in this respect exhibits a character quite distinct from the comparatively tame outline and green acclivities of the neighbouring chalk hills. Its summit is composed of strata of compact chalk, dipping east, at an angle of 5° from the horizon; and is divided into three perpendicular escarpments, having sloping terraces between them. The vertical portion of the two upper escarpments, may each be about ten feet in height; and that of the lowest is also ten feet, but its upper half is composed of indurated chalk, and the lower of syenite, a part of which is rudely columnar.

This syenite cannot, either in external aspect, or in internal structure, be distinguished from that of the cliff, and the same transition into syenitic greenstone is observable. Having made an excavation and cleared away part of the surface soil and grass, both above and beneath the syenite, I obtained the following section. Commencing from the top; compact chalk, five feet*; syenite, five feet; an irregular bed of chalk, from nine inches to one

* The grain of this chalk is closer and more compact than that of the chalk forming the summit of Torr Eskert.

foot; containing quartz pebbles, green sand, and numerous, red, siliceous grains, some of which resemble garnets, and others carnelians. This stratum rests on soft, leafy, mica slate, regularly stratified, and dipping north-west at an angle of 10° from the horizon.

The syenite is divided into large masses, which in several places are separated by intervening chalk, containing quartz pebbles and green sand, also numerous fragments of the fossils, usually met with in the green sand of the north of Ireland. The views, Nos. 4 and 5, represent the connexion of the chalk and syenite at Torr Eskert.

It is to be observed that in the vertical masses of chalk (see wood-cut, No. 4.) the numerous fragments of belemnites, shells, and other fossils, are also nearly vertical; and consequently are not in the position in which they were deposited. In examining closely the line of contact between the syenite and the chalk, it will be seen that the elevations and depressions of the outline, are accurately filled with the syenite. It is also to be observed that the chalk, in immediate contact with the syenite, is unusually compact, and that the colour is changed from yellowish white to reddish white.

No. 4.

Connexion of chalk and syenite at Torr Eskert. *a*, mica slate; *d*, chalk; *e*, syenite.

One of the specimens (No. 10.) presented to the Society's Museum * contains a wedge of chalk, included in the syenite, and the lower part is so compact as to assume the appearance of marble,

* The specimens alluded to in the Memoir are in the Museum of the Geological Society.

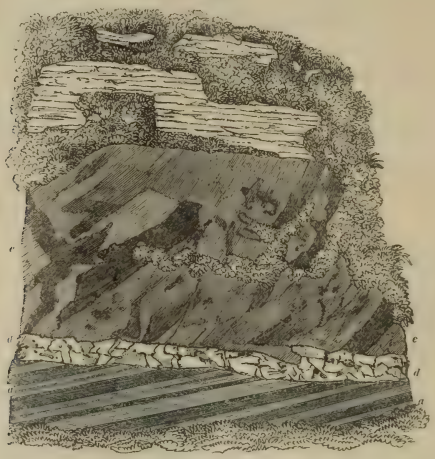
agreeing in this respect with the character which chalk usually presents, when found in contact with common whin dikes.

It is remarkable, that a small reniform mass of syenite, is included in the centre of this wedge of chalk; but is much finer in grain than the usual mass of the syenite. It is evident from its external appearance, that this small mass has not been rounded by attrition.

In another specimen (No. 11.) the chalk is nearly enveloped by syenite; and the minute projections at the point of contact are well developed.

The specimen marked No. 12. exhibits a small portion of the syenite passing through the chalk in the form of a vein; and that numbered 13. contains five small portions of chalk insulated in the syenite, and it is remarkable that the union at the contact is so perfect, that the chalk appears to form an integral part of a compound rock.

No. 5.



Connexion of the chalk and syenite at Torr Eskert. *a*, mica slate; *d*, chalk; *e*, syenite.

There are several other peculiarities which render this contact of syenite and chalk very interesting, and which may probably give rise to much discussion. The most remarkable, is the occurrence of reniform or flattened spheroids of the syenite *included* in the chalk. The positions of several of these masses, are shown to the right of the sectional view No. 4, which was drawn with great care, and accurately represents the facts when the last excavation was made: any fresh excavation will of course cause a change in the detail, but I have no doubt that the principal char acters will be continued.

Included in the collection is a specimen (No. 14.) which exhibits two, detached, flattened masses of syenite, resting on chalk. It might be argued from the smooth edges of this specimen, that the

fragments had been rounded by attrition, and consequently that the chalk which surrounds them is newer than the syenite. But it may be observed, that the syenite itself includes pebbles of quartz, similar to those contained in the green sand and chalk. This fact, when coupled with the peculiarly rounded and indented form of the upper surface of the syenite, and the smooth flattened one of the lower, leads to the conclusion, that it was injected in a fused state into the chalk, when the latter was soft or plastic; and that it may be considered similar to the small reniform fragment of syenite included in the chalk, as seen in specimen No. 10. If the chalk were not first formed, how can we account for fragments of that substance being included in the syenite, as exhibited in the drawing No. 4, and in specimens Nos. 10, 11, 12, 13; and above all, how can we account for the irregular stratum of chalk, with green sand, &c., which occurs *below* the syenite, and interposed between that rock and the mica slate, as exhibited in cuts Nos. 4 and 5?

It may also be mentioned, that it is not unusual to find chalk intermixed with trap, and trap entangled in chalk on the Antrim coast. Examples of both occur at Kenbane Head, west of Ballycastle; and in the section No. 1, appended to this paper, the southern extremity of the greenstone of Fair Head, is shown penetrating the chalk, while the chalk itself includes masses of trap.

It is perhaps unnecessary to dwell on this subject, as it is hoped that the drawings, together with the specimens, will sufficiently illustrate the relations of the mica slate, chalk, and syenite: and if it appears, that the views now put forward, have been substantiated, a new and important fact will have been added to those, already described by other observers, which may ultimately lead us to attribute a comparatively recent origin, not only to syenite veins and to greenstones formerly called primary, but also to many other crystalline rocks.

I have long doubted the existence of true beds of the large grained crystalline greenstone or granite, in schistose sedimentary rocks, being of opinion that if carefully examined, they would, like the syenite now described, prove to be intrusive veins, and not beds subordinate to those rocks; but I forbear entering further upon this subject at present.

October, 1835.

Cervical Vertebræ of Ichthyosaurus from the Lias of Lyme Regis and Street

XV.—*On certain peculiarities in the Cervical Vertebræ of the Ichthyosaurus, hitherto unnoticed.*

By Sir PHILIP GREY EGERTON, Bart., V.P.G.S.

[Read June 8, 1836.]

SOME of the facts contained in the present Memoir, were announced to the Geological Society in a short notice, read May the 13th, 1835*. Since that period I have followed up the inquiry by the examination of a great variety of Saurian relics; and I am now enabled to enter more fully into the details of those facts, the bare occurrence of which was all I could safely offer in the former communication. By the aid of the illustrations given in Pl. XIV, the anatomical details will, it is hoped, be rendered sufficiently intelligible, to enable the reader to judge of the accuracy of the conclusions, which I have founded upon a consideration of them.

Atlas and Axis.

In the spring of 1835, I procured from Miss Anning (whose zeal and intelligence are well appreciated in the Geological community) a specimen from the lias of the neighbourhood of Lyme Regis, showing the atlas of a small Ichthyosaurus, apparently anchylosed to the second vertebra of the column. Having directed her attention to this circumstance, she informed me that though she had frequently found similar bones, yet it had never happened to her to see them disunited, even when a dislocation of every other bone of the animal to which they belonged, had taken place. In less than a week I received from her an atlas, seven inches and a half in diameter, corroborative in a remarkable degree of her former observations. The axis was firmly united to it, and she assured me that this was the only instance, in which any two bones had been found in contact, after she had collected a large portion of the skeleton to which it belonged. I have subsequently had opportunities of examining nearly thirty specimens of all sizes, and probably of several species, in various

* See Proceedings, vol. ii., No. 41, p. 192.

stages of growth, some in their natural position in the skeleton, others detached and rounded by attrition on the beach, all of which exhibited the same peculiar features. Two views of a very perfect specimen, from the collection of Lord Cole, which I have selected to illustrate the following details, are given at plate XIV., figs. 1 and 2.

Upon referring to fig. 2 it will be seen that the outlines of the two vertebræ are very clearly defined; I have found, however, by the examination of polished sections, that in the internal structure the bony texture generally extends without interruption from one to the other*. Once only have I succeeded, after the sacrifice of several specimens, in obtaining a forcible separation of the two vertebræ, and in this case I found that no intervertebral cavity existed, the bones articulating together by surfaces perfectly flat and even. (Fig. 3. A. B.) It is probable then, that in individuals of tender years the atlas and axis existed as distinct bones, but the extreme rarity of specimens in this condition, leads me to imagine, that the union between the two, took place at a very early period of the animal's life.

The atlas differs very materially from the other bones of the spinal column. It is furnished anteriorly with a semicircular cup (Plate XIV. fig. 1. *a.*) for the reception of the articulating tubercle of the basilar occipital, widely different from the conical cavities of the other vertebræ; for whereas in these the margin of each intervertebral cup is produced into a thin edge for articulation with its neighbour, in the atlas it is rounded into the form of a thick and solid lip, bounded on either side by a broad and rugged surface occupying the position of the costal articulation, which probably served for the insertion of the ligaments connected with the head. (Fig. 2. *a.*)

The axis, as I have already remarked, is flat anteriorly for articulation with the atlas. (Plate XIV. fig. 3. B.) It resembles the dorsal vertebræ in the form of the posterior cavity, as also in being furnished with bases for the attachment of ribs. (Figs. 2. *d.* and 3. *c.*)

Subvertebral Wedge Bones.

I now arrive at a very remarkable feature, at once distinguishing the first and second from the other bones of the spinal column, viz. the configuration of the inferior part of the vertebral body. On the under surface of each bone there exists an unusual enlargement in the form of a solid wedge-shaped process placed transversely to the smaller diameter of the vertebræ. By this arrangement four triangular planes are produced, disposed in the following order. The first and largest (Plate XIV. figs. 1 and 2. *b.*), is based upon the lower anterior margin of the atlantal socket, having its apex directed downwards and backwards until it meets the apex of a similarly shaped, though

* See a polished slab in the British Museum from the collection of the late Mr. Bullock.

smaller plane (fig. 2. *c.*) proceeding downwards and forwards from the posterior margin of the atlas. The third of like shape and size with the second, (fig. 2. *f.*), extends from the anterior margin of the axis, and joins the apex of the fourth (fig. 2. g.) which inclines forwards from the posterior portion of the same bone. This fourth plane is considerably smaller than the others, and corresponds in size with a fifth (fig. 11. *a.*), placed on the anterior border of the third cervical vertebra. When, therefore, the three anterior vertebræ are in their natural position, the arrangement of the five planes is as follows. The first and largest occupies the lower front of the atlas; the second and third, by the union of their bases, produce a triangular socket on the under surface of the atlas and axis; and a second smaller socket is formed between the axis and the third vertebra, by a similar disposition of the fourth and fifth planes. Having endeavoured to render intelligible the arrangement of these parts, I shall proceed to describe three peculiar bones which articulate with the above-mentioned planes, and which I propose, from their form and position, to designate *subvertebral wedge bones*.

The fortunate acquisition of an Ichthyosaurus having the first subvertebral bone *in situ*, enables me to omit a series of arguments by which I was prepared to show, that a bone did exist supplementary to the atlantal socket, and that the specimen represented at Plate XIV. figs. 4, 5, 6. was to be ascribed to this position in the skeleton*. The second bone of the series is frequently found with the atlas and axis, and is not uncommonly fixed in its position by anchylosis. The third bone is of rare occurrence, in consequence of its diminutive size, and is probably in some species altogether wanting. Fig. 7. is an accurate representation of the cervical apparatus of the skeleton I have above mentioned, and shows the three subvertebral bones so far displaced as to allow their respective sockets to be seen. Fig. 8. *a. b. c.* is an enlarged view of the same bones seen from below.

First Subvertebral Wedge Bone.

This bone is of great strength and solidity. Its form triangular. The under surface is thickened into a central projecting boss, Plate XIV. figs. 5 & 6. *a.*, from which it spreads out anteriorly into two alæ, representing two angles of the triangle. (Figs. 4, 5, 6. *b.*) The base between these points is occupied by a smooth semilunar socket (fig. 4. *c.*) which receives the lower hemisphere of the articulating tubercle of the occiput. A rapid contraction of the bone posteriorly forms the apex of the triangle which is slightly truncated, (figs. 5, 6. *d.*) The upper portion of this

* I have just seen in the magnificent collection of Mr. Hawkins an Ichthyosaurus from the lias of Somersetshire, having the first and second bones in their natural position.

bone forms a rugose articulating surface, (fig. 4. *a*.) extending backwards from the semilunar socket until it meets at a considerable angle a smaller facet (fig. 4. *d*.), formed by the truncation of the distal extremity of the bone. The former corresponds in size with the plane on the front of the atlas, and articulates with it; the latter abuts against the anterior extremity of the second subvertebral bone. In order that the arrangement of this part of the skeleton may be fully understood it will be necessary to consider the nature of the connexion between the head and trunk of the animal. In the several species of Ichthyosaurus, the proportion of the head to the total length of the body varies considerably, but is in all very large. The articulation with the trunk is effected by a ball and socket joint, between the basilar* portion of the occipital bone and the atlas. How far the mechanism of this joint would have been complete without the aid of a supplementary bone will be immediately perceived by fitting the atlas to its corresponding occipital bone. By the application of this test I have invariably found the cup of the atlas incapable of receiving more than two thirds of the occipital condyle. In well-preserved specimens this portion of the articulating process is defined by a slight depression on its surface† (fig. 7. *m*.). This seeming deficiency in the socket of the atlas is more than compensated for by the supplementary bone I have above described; for the angle at which it unites with the atlas (fig. 6.) is so contrived that the semilunar socket on its proximal extremity does not coincide with the plane of the atlantal socket, but projects forwards in such a manner as to embrace the whole lower circumference of the occipital condyle. An universal joint is thus effected at the same time that the subvertebral bone affords by its form, solidity, and position, a most powerful fulcrum to restrain the downward pressure of the animal's head.

Second Subvertebral Wedge Bone.

This bone (Plate XIV. fig. 7. *h*.), like the one already described, is strengthened below by a boss of solid bone. It is generally lozenge-shaped, but variations occur both in its form and proportions, probably consequent upon the species and age of the animal to which it belonged. Above, it is divided by a transverse elevation (fig. 3. *b*.) into two facets articulating with those between the margins of the atlas and axis, and, in front, it impinges upon the extremity of the first subvertebral bone, affording it a strong basis of attachment, and greatly enhancing its power.

Third Subvertebral Wedge Bone.

This bone (Plate XIV. fig. 7. *i*.) resembles the second in form, but is considerably smaller. It is lodged in a depression between the axis and the third cervical vertebra, and imparts much firmness to these bones, at the same time that it does not materially affect the amount of motion between them. I have before stated that the third subvertebral bone occurs rarely, and is probably in some species altogether wanting. This may reasonably be inferred, if there be any truth in the argument, by which I shall endeavour hereafter to show the office, which I believe these bones were destined to perform.

Cervical Vertebræ.

The third cervical vertebra of those species of Ichthyosaurus which are

* This appears to have remained distinct from the other elements of the occipital bone in individuals of every age and species. Mr. Owen remarks that evidence is thus afforded of a languid circulation in this family of Saurians.

† See a gigantic vertebral column in the British Museum.

furnished with three subvertebral bones, is characterized by an articulating facet on its anterior margin. (Plate XIV. fig. 11. *a*.) Certain modifications appear also to have obtained in the form of the intervertebral cavities in this region of the spine, producing a diminution of capacity to a greater or less extent as compared with those more distant from the head. A remarkable instance of the contraction of the cavity, combined with other striking peculiarities is shown at figs. 9 & 10. The vertebra there represented is seven inches in diameter, and was probably the fourth. It belonged to the same animal as the large atlas already mentioned. The anterior cavity is here reduced to a small cylindrical depression, not larger than a shilling in circumference. (fig. 9. *a*.) The remaining surface is nearly flat for articulation with the antecedent vertebra. The fifth vertebra resembles the fourth, but is somewhat smaller. Both are furnished behind with conical cavities of no great depth, for the reception of intervertebral matter. These bones exhibit a remarkable contrivance, by which the security of their articulation was much increased, although at the expense of a small amount of flexibility. In front of each, near the lower margin, a depression is so situated as to receive a corresponding eminence projecting from the contiguous vertebra (figs. 9, 10. *b*.), whilst on the upper margins similar depressions and projections are placed in the inverted order, affording twofold checks against the danger of dislocation. (Figs. 9, 10. *c*.)

The combined result of this construction, and of the reduction of the intervertebral cavities, must have been a considerable increase of power in this part of the spinal column. I shall only further remark that, proceeding from the lumbar vertebræ towards the head, the column attains its minimum diameter about the fifth cervical vertebra, from which point to the occiput it increases in size very rapidly.

Having concluded the anatomical details, I now proceed briefly to examine how far the structure I have endeavoured to describe agrees with the design of the other parts of the animal fabric, in adapting the Ichthyosaurus to the peculiar conditions under which it was destined to exist.

Whether we consider the osteological characters which I have detailed individually, or collectively, in their most contracted, or in their most extended state of development, we see in them provisions well calculated to increase, to a greater or less amount the power of the cervical region. We also see that this increase of power, is combined with only a slight decrease of the flexibility, so admirably provided for in the other parts of the spinal column. Let us now inquire, how far this combination of motion and strength in the neck of the Ichthyo-

saurus, is compatible with the ideas we may have formed of the exigencies of the animal, from our previous knowledge of its structure and habits. It has been established, upon evidence the most conclusive, that the Ichthyosaurus was a carnivorous reptile, inhabiting the sea, and breathing air, and the more we study its organization the more we see the beautiful adaptation of all its parts to such a mode of life. The lengthened snout, capacious jaws, and prehensile teeth, enabled it to seize and retain its slippery prey; while the broad expanse of tail, and the fish-shaped vertebræ, afforded a powerful apparatus for progression through the fluid that it is supposed to have inhabited, in pursuit of the finny tribes, which, principally, constituted its food. This combination of organs of pursuit and prehension for the capture of its prey, would have been of little avail, without the power of control and direction; consequently we find in the thoracic region, a powerful apparatus connected with the anterior extremities, to regulate and govern the movements of the body.

Mr. Conybeare, speaking of this structure, says*, "The form of the sternal arch, and the broad surfaces of the clavicles is such as to impart great strength to the chest, enabling the animal to breast the most disturbed waters, and affording an extensive surface for the attachment of powerful muscles to assist in moving the anterior extremities." It was further necessary that the head, constituting one-fourth of the entire length of the animal, should be furnished with adequate powers to enable it, not only to cleave the waves with steadiness and ease, but to obey each impulse, in directing the pursuit, with quickness and precision. If we examine living structures, we find in the whale, a fulcrum for the support of the ponderous head in the anchylosis of the cervical vertebræ. In fishes we find provisions for rapid progression in the construction of the spinal column. The Ichthyosaurus required a combination of the two powers; and as former observers† have demonstrated most clearly the beautiful adaptation of the animal's organization for progression through the waters, so I trust I may no less clearly have established, by the foregoing details, the existence of contrivances in the cervical vertebræ, fully sufficient to have afforded that enlarged amount of power, which the habits of the animal, and the proportions and arrangement of its parts would seem to suggest to have been almost necessary to its existence. Doctor Buckland, when speaking of the "Ossemens Fossiles," and of the author of that work, in his Bridgewater Treatise, says‡ "Nothing can exceed the accuracy of the

* Geol. Trans. 1st Series, vol. v. p. 578.

† Geol. Trans. 1st Series, vol. v. p. 559 et seq. 2nd Series, vol. i. p. 103 et seq.

‡ Vol. i. p. 140.

severe and logical demonstrations, that fill these volumes with proofs of wise design in the constant relation of the parts of animals to one another, and to the general functions of the whole body. Nothing can surpass the perfection of his reasoning in pointing out the beautiful contrivances, which are provided in almost endless variety, to fit every living creature to its own peculiar state and mode of life." If I have succeeded in adding one instance to those amassed by the illustrious Cuvier of "conformity of design," I trust the imperfections of the foregoing memoir may be pardoned.

Since this paper was written, I have received from Mr. Hawkins (whose splendid collection of Lias Saurians far exceeds any I believe in the world) the atlas and axis of an *Ichthyosaurus tenuirostris* found near Street. (Plate XIV. fig. 12.) The bones are firmly anchylosed together. The articulating facet on the front of the atlas is large. The second subvertebral bone is *in situ*, and is much smaller in proportion to the first than those I have before seen. The third subvertebral bone is entirely wanting. This interesting specimen confirms the statement I have before ventured, that modifications in the forms and proportions of the cervical apparatus, would probably be found in animals of different species and age.

COAL FIELD. *FOREST OF DEAN*

by

H. T. De la Beche Esq. F.R.S.

XVI.—*Notes to accompany a Geological Map of the Forest of Dean Coal-field.*

By HENRY MACLAUCHLAN, Esq., F.G.S.

Employed on the Ordnance Trigonometrical Survey.

[Read February 6, 1833.]

THE following notes were collected during the progress of the Ordnance Survey in 1830, but some additions were made at a subsequent visit to the Forest of Dean. It is desirable that I should acknowledge the several authorities from whom information has been obtained.

From occasional intercourse with the Rev. W. D. Conybeare, I derived the little knowledge which gave rise to these notes.

The memoir by Professor Buckland and the Rev. W. D. Conybeare, on the south-western coal district of England; as well as that by T. Weaver, Esq., on part of Gloucestershire; and the section of the Forest of Dean by D. Mushet, Esq.*, have served as foundations to the map† and the notes.

Charles Bathurst, Esq., of Lydney Park, supplied the minute observations respecting that neighbourhood, particularly those relating to the fault between Lydney and Denbigh Lodge.

D. Mushet, Esq. and Mr. Henry James, of the Forest of Dean and Lydney, greatly assisted me, not only in marking the outcrop of the beds of coal, but in pointing out where the best information could be obtained.

Mr. Moses Teague, of Parkend, supplied the outcrop of the two upper beds of coal from actual observation; and the accuracy of the northern curve of the same beds was confirmed by Mr. James Bennett, of Drybrook, who has extensive works on the spot.

From information supplied by Aaron Hale, of Coleford Meend, have been laid down the fault from Worcester Lodge to Bury Hill, and the probable range of the Coleford high delf coal, between Bic Slade and Carter's-piece Meend‡.

The author's colleagues on the Ordnance Survey, have from time to time

* Geological Transactions, vol. 1. of the Second Series, pp. 280, 288, 352, also Plate 32, 38, and 39.

† Plate XV.

‡ It is suggested that this range should be received with caution, notwithstanding it has been partly confirmed by Mr. Mushet; as it is difficult for a beginner to comprehend perfectly the remarks of a practical miner.

supplied much information and many extensive boundaries; but, as these observations as well as his own, were made in the course of duty, it is not presumed that they are so precise, as if undivided attention had been given to the subject. The greater portion of the outline from Mitcheldean to Penhow, was traced by Mr. John R. Wright and Mr. R. Wright.

Old Red Sandstone.

The old red sandstone, which constitutes so large a portion of Herefordshire, and passes under the coal-field of the Forest of Dean, may be divided into three portions.

The lowest*, containing beds of cornstone, occupies the flat district between Hereford and Kenderchurch, stretching on the north-west from Wormbridge to the east of the Black Mountain, and by Hay and Talgarth to Brecon: on the north-east it extends from Wormbridge by Dewsall and Aconbury, and crosses the Wye, near Fownhope, towards Sellershope, where the strata are thrown up by the outcrop of the transition series. Along the course of the Wye, to the south of Hereford, these beds are overlaid by diluvium; and to the south-west as far as Thruxton. The sandstone, however, may be observed at intervals; and the occurrence of a bed at Brandon Hill, near Bullingham, dipping to the north, renders it probable, that a line of elevated strata ranges from Kender-church, in an irregular direction, to Shucknell Hill, to meet the anticlinal line which extends from May Hill to the apex of the Bristol coal-field. The same line of elevation is supposed to pass from Kenderchurch, southward by Clytha (where the transition beds are thrown up) to Usk.

The next bed, which from its position may be called the middle, is a conglomerate, and may be easily distinguished by its elevated position, forming the northern escarpment of the hills, from the Graig at Grosmont, where it attains the height of 1380 feet, by Garway Hill and Aconbury, at which point its dimensions are much diminished, to Capler Camp on the Wye. This conglomerate, it is presumed, may be an outlier of that which occurs at the Doward Hill on the Wye, near Monmouth (Map, Pl. XV.); and the presumption is strengthened by a want of connexion between the beds at a lower elevation, as far as has been observed; and by a coincidence of opinion with Mr. Mushet of Coleford.

It is supposed that this bed of conglomerate, occupies the elevated summit of Trelloch Beacon; and that it passes by Wye Wood Common, and Chep-

* The district occupied by this division, and the greater part of that, by the second or middle, are not included in the map.

stow Park to Wentwood on the Usk; and that it is overlaid by the new red sandstone near Newport on the same river.

This conglomerate or hard grit, it may be scarcely necessary to observe, is some way below the top of the old red; and it sometimes forms two distinct beds*.

The hardness, as well as the number of the pebbles, varies; but there is scarcely a place along the outcrop of the old red, where fragments at least, of the conglomerate, are not seen (except north-east of Lydney, where the conglomerate is cut off by the fault); and it usually presents a steep ridge, succeeded by the soft ground of the upper beds and of the limestone clay. These argillaceous strata often throw out springs, accumulated in the limestone rocks above†.

The upper bed of the old red sandstone, is given in Mr. Mushet's section as twenty fathoms in thickness; and it rests immediately on the conglomerate.

The Penyard and Chase Hills, near Ross, (Map, Pl. XV.), are outliers of this upper bed and the subjacent conglomerate, the latter constituting, all around the hills, projecting masses which dip about 12°, so as to take the ground again, and form the rugged and picturesque scenery from Hope Mansel, and the bold promontory of the forest coal-field south of Lea, as well as the escarpment by Warm Hill, Goodrich, and Huntsham to the Doward and "Buckstone," where a highly inclined mass of it, forms an object of interest to the antiquary as well as to the geologist.

The similarity between the conglomerate bed of the old red sandstone and the millstone grit, has led some miners to sink for coal in the former, about a mile to the north-west of Penhow. Had they extended their observations, on the surface, a little more to the south-east, they would have seen the carboniferous limestone, which must have been familiar to them, dipping conformably to, and resting upon, the strata they were piercing; and they would have saved much expense and waste of time.

At Bircham Hill, near Newland ($3\frac{1}{2}$ miles south-east of Monmouth), the old red sandstone appears to have been forced up through the carboniferous limestone; a supposition which is strengthened by the strata dipping in every direction; but it must be observed, that the valley from Newland to Red-

* At Chapel Hill, near Lydney, there seems to be a second upper layer of it very distant from the first, but this appearance may be due to a fault. Near Monmouth, at the Kimin Hill, and Buckstone, there are similar indications, and the conformation of the ground, and a general view of the hills from Trelleck to Penhow, would lead to a similar conclusion.

† A very micaceous stone sometimes occurs in the upper part, near the conglomerate. Quartz pebbles are sparingly dispersed in beds above the hard conglomerate, and for some way below it.

brook, is cut out of the sandstone for the greater part, and is connected with Bircham Wood. On the other hand, the occurrence of the conglomerate at Bircham, when taken in connexion with the diversity of dip, supports the supposition, of an upthrow in this particular spot.

The surrounding limestone dips regularly into the coal-field, and is apparently undisturbed.

It may be worthy of notice, that this conglomerate, at Bircham, forms, with that at Buckstone on the north and Ailberton Common on the south, a line of conglomerate nearly parallel to the general conformation of the coal-field on the south-west.

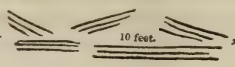
Near Ailberton Common, the dip of the old red is not always great, but varies through every degree of inclination, and over a large part of the surface, is less than 30°.

The strata are often nearly or quite horizontal, and when that is the case, a slight undulation makes the dip vary to quite a different point of the compass, as is indicated by the arrows in the map.

This nearly level position of the *old* red sandstone greatly increases the difficulty, where it occurs, of distinguishing that formation from the *new* red sandstone; but in general, the upper beds of the old red are more highly inclined than the lower; though in the Tidenham Chase Hills, south of Hewelsfield, where such is the case, the mountain limestone conforms to the gentle dip of the lower beds. Sometimes, the angle not even of the upper beds, is great, particularly along the whole of the Ailberton Common district.

In this country, the distinction mentioned in the Geological Transactions (2nd series, vol. i. p. 284,) between the middle and lower divisions of the old red, seems hardly maintainable. Cornstone nodules occur in the very lowest beds in the Severn Cliffs about Gatcombe, opposite the transition limestone; also in the cliffs on the left bank, between the outcrop of that limestone and Sharpness Point; and they are found at Blakeney. On the other hand, the flagstones are by no means confined to the lower beds; but are more common in those of the Mill Rough and the hills west of Blakeney, in a higher part of the series than that in which any cornstone nodules occur.

For a few miles east of Lydney, the country, for the most part, consists of clay, except perhaps the upper beds along the Mill Rough and Horage Wood; but even in these localities, the sandstone by no means exclusively prevails.

The position of the small stone beds of the old red, sometimes varies singularly near the surface, lying thus,— 

, owing apparently to unequal depositions. Such sections occur in the turnpike-road east of Alvington, and some way east of Lydney.

Along what may be called the Blakeney range of the old red, from Newnham to Ailberton, the dip is from the river, or towards the Forest.

A second dip, always gentle, but quite different, viz. towards the north-east, is met with in the Ailberton Common ridge, also from Ailberton Chapel to Bream Lodge, and in the lower strata belonging to the old red, which extend nearly to Woolaston.

This ridge of conglomerate is intersected, in one place, by a cross fault, raising the part furthest from the Severn, and affecting the outline of the limestone, but the dislocation cannot be traced into the body of that formation, or far into the lower part of the old red. The line of hills, which may be called the Chase Hills, from near Bream Lodge, by the east of Hewelsfield, to Tidenham, have a third dip nearly parallel to the first. Each of these, where it joins the next, seems generally to do so by a sudden line, not graduating round; but this is difficult to prove with certainty. The upper strata near Bream Lodge are an exception, as they seem clearly to bend evenly round, including the conglomerate at Prior's Meend.

Carboniferous Limestone.

The carboniferous limestone surrounds the Forest of Dean coal-field, with the exception of the line of fault between Lydney Park and Denbigh Lodge, a distance of four miles. According to Mr. Mushet, a bed of iron ore divides the lower and more crystalline, from the upper and more argillaceous and sandy strata. A section of these beds is well exposed on the side of the tram road, about a mile below Cinderford Bridge, on the east side of the Forest, and at Lidbrook on the north.

There is a small outlier of the coal measures, including the lowest bed of coal at Howl Hill; it does not appear, however, to rest on the same bed of limestone as that in the large field at Ruerdean, but on a more argillaceous and thinner stratum, which is not supported by the bed of iron ore or lower crystalline limestone. To the east both the limestone and the coal thin out, or are cut off, the coal measures resting on the old red sandstone. The valley of the Wye is cut through the limestone only, for on the summit of Copped Wood Hill, the same argillaceous beds occur again, and all attempts to trace a continuation of the outlier of coal, have been unsuccessful.

On the Doward Hill the iron ore bed reappears, and the ancient workings on the summit of the Little Doward, may have been mistaken for an entrenchment, on that commanding and military position.

The dip of the beds at Howl Hill is very slight, but it increases westwards towards Doward Hill, where it is considerable.

At a place called "the *Dunder* Hole" (*Thunder?*) on Bishop's-wood, a stream sinks through the strata with a considerable noise, and emerges again in the valley to the south, a little above Bishop's-wood House, where it is perhaps thrown out by the bed which underlies the great stratum of limestone at Ruerdean. A similar occurrence takes place in the limestone about a mile to the south of English Bicknor.

Near the "Dunder Hole" is a bed of gravel in the position of the millstone grit, but it is very different in appearance from the grit in the Forest. It has much the character of diluvium; and if there were an aperture through which the Wye at any elevation could have deposited it, the similarity in appearance would lead to such a conclusion.

There is a small outlier of the carboniferous limestone at Penallt Common, about three miles south of Monmouth; it dips conformably with the sandstone on which it rests, and is so valuable for manure in that clay and sandy country, that it is nearly worked out, though it must have covered two acres in the first instance. There is no appearance of the coal strata.

Coal Measures.

In tracing the outline of the coal measures, Mr. Mushet's Section, published in the 1st volume of the Geological Transactions, 2nd Series (Pl. 32. No. 5.), has been particularly useful, as it crosses the field in almost the only direction, which includes all the strata.

The beds of coal may be conveniently divided into two series; 1st, the *rock beds*, or those separated by a coarse sandstone, including all the seams from the lowest or "Trencher," to the "Brazilly," and, 2ndly, the *argillaceous beds*, or those above the Brazilly, and characterized by shale.

Of the lower series, the outcrops of only the "Trencher" and the "Coleford High Delf" have been traced almost continuously around the field; but these beds differ in their relative distances and qualities; and it is said that one increases in value where the other decreases.

At Lydney Park the "Coleford High Delf" and "Trencher" are not well defined at the angle, the outcrops being there very obscure. From this point they increase in dip, with the rising ground, to Bream's Eaves, and afterwards decrease again, but at Gorse Hill and Coleford Meend, they become horizontal, and crop out to the westward, more from the declivity in the ground than from their ascending position in that direction. This observation will apply to their outcrops on the north also, from a little south of Symmonds' Gate to Joyford and Carter's-piece Meend.

At this place the line of division*, ranging from Bic Slade to Carter's-piece

* This line is nearly parallel to what is assumed to be the line of greatest depression, or central line of the field or floor, which rises to the north at about 10°.

Meend, between the inclined or eastern and the horizontal or western part of the bed, emerges to the surface, and the coal crops out in opposite directions, for some distance, from the Whimberry Slade to Carter's-piece Meend; but beyond the latter point the two beds crop conformably with those above them, into the valley of Lidbrook.

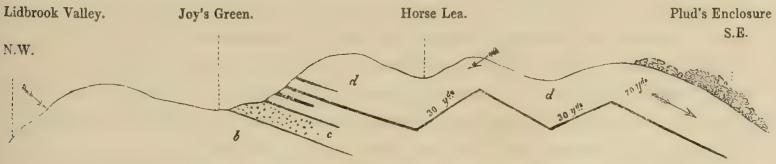
Mr. Mushet observes, that this line of division causes the western side to dip gently to the west, and afterwards to rise again, forming on Coleford Meend a slightly inclined basin rather than a horizontal bed.

At Oakwood Mill the "Coleford High Delf" is not worth working, probably from the effects of a fault.

The divergence observable in the outcrop of the beds to the northward, arises from the decrease in their angle of position.

The Trencher Delf begins to be workable coal about north of Bream; but its range has been traced from the clay observable in its line of outcrop; and though of little consequence to the miner, it should not be altogether disregarded by the geologist.

At Lidbrook Valley, on the north of the coal-field, there is a contortion on each side, which throws down the High Delf coal, in one instance, seventy yards, and in two others, thirty yards each (see the accompanying diagram which is parallel with the strike or at right angles to the dip of the beds).



b. Carboniferous limestone. *c.* Millstone Grit. *d.* Coal measures.

The ten yards of clod ceases as a covering to the coal before we reach Carter's-piece Meend, and its absence is probably connected with the effects of the fault; for on showing this section to Mr. Mushet, he confirmed the details, as received from a practical miner, but reversed the order, making the double contortion on the western side of the valley, and the seventy yards depression at one step, on the eastern, where this section is represented to be.

In the double step, the descending portions are useless coal, and represented to be dust and dirt.

The local name for this contortion is "*Horse*," whence "*Horse Lea.*"

From Worcester Lodge near Coleford, to Bury Hill, is a line of disturbance, the course of which is marked, on the surface, by a series of ponds, called Howler's Well, Leech Pool, Crabtree Pool, Hooper's Pool, and Hall's Pool. It is possible the water may be kept up by the clay in the fault, which is said to be 200 yards thick, extremely hard, full of silicified wood; and when acted on by powder, it separates without disturbing the surrounding mass, yet causes much trouble to the miner.

One branch of the fault ranges to Elmore Mill; and others are said to diverge along its course, but they have not been defined.

These are the only interruptions to working the coal of any consequence which have been ascertained; those found occasionally in other pits occur here, but they are of temporary inconvenience.

Above the "Trencher" is a bed called "the Spider," which is wrought at Gorse Hill, about a mile south of Coleford, and in no other place as far as could be ascertained.

Above the "Coleford High Delf" is the "Whittingtons Delf," known also as the "Yard Coal." It is worked principally in Bream district, but is found at Dark Hill, and its clay is said to have been cut through in a shaft sunk to the west of Birch Hill Lodge, though no trace of coal was observed. From its position in the series, it is presumed to be the same bed, with that which crops out again on Carter's-piece Meend, at Nail Bridge; and it thins out on the west side of the field in the Haywood Enclosure, with several others, including the strata of sandstone in which the coal beds occur. This fact was proved by a level driven by Mr. Moses Teague at Cinderford Bridge from the "Churchway," one of the clay beds, to the "Coleford High Delf," without meeting with any other coal seam. At Staple-edge Enclosure the "Whittingtons" is brought in again with the strata of sandstone, and is traceable thence to the Bream district.

The "Nag's-head," or "Yorkley" seam, is nearly parallel to the "Brazzilly" above it, and the "Whittingtons" below, except in Ruerdean-hill Enclosure, where the true position has not been well ascertained. The outcrop of the sandstone beds, may be easily traced by the step made in the wearing away of the clay and coal, leaving a projecting hard ledge of rock. In the clay beds there is no such guide; and the information collected from the miners, and occasional traces of coal, have been relied on.

As the outcrops of the clay-bed seams are faintly indicated, no attempt has been made to trace them on the surface above the "Parkend High Delf". This bed is occasionally called the "Lowery", and is well known around the field by these names. Those above it are not so generally worked, and the outcrop has not been so well ascertained. The uppermost seam, called the "Woor Green," is known only near Cinderford Bridge, or a little east of Yewtree-brake Lodge, where it has been wrought. An outcrop near Crab-tree Lodge is supposed to belong to the same bed; and one cut through in digging the well at the "Speech House," may be a continuation of it; and this supposition is in some measure confirmed by the structure of the ground. The dotted line in the map defines the probable course of the outcrop.

The beds between this and the "Parkend High Delf", are enumerated in Mr. Mushet's List and Section (Geol. Trans., 2nd Series, vol. i. p. 288), but all endeavours to trace them around the field have been unsuccessful.

An attempt has been made in the map to mark the outcrop of the principal beds of coal. Those belonging to the Rock or Lower Series, being further from each other and thicker, are best known. Where the information was obtained by personal observation, or from good authority, the outcrop is marked by a continuous line; but where the data were doubtful or conjectural, by a broken line.

The "Churchway" or "Oakenhill," and the "Parkend High Delf" or "Lowery" (Lower-high?) being most worked or best known, have been selected to define the range of the upper or argillaceous beds, and the five others (according to Mr. Mushet's List), which occur between them have been omitted, from the crop being confined to the intervening narrow space.

Those above the "Parkend High Delf" have not been ascertained satisfactorily enough to be inserted, and the "Woor Green Delf" has been dotted in, from conjecture, but after an attentive observation of the construction of the ground, with the exception of its known outcrop near Cinderford.

Iron Ore.

The stratum of argillaceous iron ore, worked near Cinderford Bridge, occurs immediately below the Trencher coal, and probably accompanies it round the field, though the workings have not been sufficiently extensive to prove it.

In the neighbourhood of Ailberton and towards Bream, the very uppermost, and nearly the lowest beds of the limestone, seem to be those which produce iron, but principally the uppermost. The position is marked by a line of rocky ground, some parts of which, called "scowls", are the effects of ancient excavations, and are nearly continuous from the Old Park Wood to beyond Clearwell.

The limestone which occurs in the millstone grit at Clearwell Meend is oolitic, and partly shelly; but it is not thick, though probably continuous to Oakwood Mill.

Newent Coal-field.

The Newent coal-field, though not included in the map, deserves a brief notice. The boundary of the field is not easily defined; but its northern and western range may be sufficiently understood by drawing a line from Oxenhall Church westward along the brook, to the road from Newent to Ross, a little to the west of Kilcot Green; thence it may be traced on the west of Kilcot Wood, where the coal measures are well marked, and along the road to Aston Ingham as far as the end of the wood; and afterwards by the western edge of Clifford's Mine, or Meend, to where the common land joins the Newent Woods, and even for a short distance within the woods. At this place the coal

measures appear to rest upon the transition series, but at Kilcot Green, or rather to the west of it, on the old red sandstone.

The eastern side is overlaid irregularly by a conglomerate of the new red system, formed principally of siliceous pebbles; and it occasionally assumes the appearance of a bed of gravel; but in no case does it resemble the magnesian limestone. Over this bed are other similar conglomerates which alternate with strata of sandstone, dipping at a low angle (5°) to the eastward.

The western side of the field is composed of a fine-grained sandstone, with small quartzose particles occasionally disseminated through it; the stone is generally iron shot, and sometimes thinly laminated, and contains specks of coally matter.

At Hill House, previous to working the coal, a boring was made to the depth of fifty yards, and the following beds were passed through, according to information received from one of the workmen employed in the undertaking.

Red clay	30 yards (new red sandstone).
Sand rock	4 feet.
Clod or clay.....	8 feet.
Coal.....	7 feet.
Clod.....	4 feet.
Coal.....	2 feet 6 inches.
Clod	15 feet.
Coal.....	4 feet.

The rest of the boring was through clod or clay.

The seven-feet coal was the bed principally worked; but it was much disturbed, and dipped rapidly, or two feet in a yard, to the north-east or east.

In 300 yards, four faults of considerable magnitude were encountered, and the coal contained a large quantity of sulphur. These circumstances, with the canal bringing the Staffordshire coal so close to the field, may have caused the relinquishing of the work.

Several other attempts have been made at Bowlsdon Farm, about a mile to the south-west of Newent; where the coal is apparently near the surface; and, as it is said to be seven feet thick, it is probably the same bed as that which was worked at Hill House. The fuel, however, is better, and less charged with sulphur than at that point. No engine was used, but numerous pits were dug, from which it may be inferred, that unskilful means were employed to extract the coal. No attempt has been made for several years.

It is possible that the nearness of this coal-field to the anticlinal line, ranging from the valley of Woolhope by May Hill to the Severn, may be the cause of the disturbances found in the strata; for the measures are so far advanced to the westward, at Clifford's Mine, as to rest upon the transition beds.

The Fault between Lydney Park and Denbigh Lodge, Forest of Dean.*

It has been correctly stated† that along a certain portion of the edge of the Forest coal-field, the limestone is cut off by a fault. This fault extends

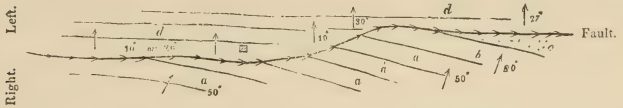
* See Map, Pl. XV.

† Geol Trans. 2d Series, vol. i. p. 286.

somewhat further, though not in a completely straight line; for near the west end of Ailberton, where the strata dipping with those at Ailberton Common, join the beds which dip conformably to the Blakeney range, a fault begins, separating these two dips from one another.

The strata which this fault divides, in proceeding northwards, and in which three different dips appear, are, first, old red on both sides; then, after passing the Chapel, old red on the right, and limestone on the left; in Lydney Park there is limestone on both sides; then at the back of the Red Hill, the fault divides the millstone grit on the left from limestone on the right. It afterwards makes a little turn to the right, apparently just beyond the junction with the lower coal, and cuts across the end of the limestone first, and then of the upper beds of the old red, and of the conglomerate, and some of the beds under it. At the same time the strata to the left of the fault, which are here the coal measures, change their direction, and dip thenceforward nearly as those on the right. From that point, therefore, the fault is marked by the omission of the limestone, on the surface, and not by any great difference of dip.

For some distance, the strata on each side, are nearly parallel to one another and to the fault (see the accompanying diagram); but after entering the forest, it is conjectured, for it is difficult to determine from the thickness of the new plantations, that there is a sort of converse in some respects from that which occurs near Lydney; for while the coal measures (*d*) continue to range parallel to the fault, the upper beds of the old red (*a*), which had been cut off near Lydney, gradually and obliquely come in again, as inferred from the dip; and then at Denbigh Lodge the fault turns for a short distance at about 45° to the left, and cuts across the end of the conglomerate (*á*), the beds above it (*a*), and the limestone (*b*), which are thus restored to the surface, at the valley of Blackpool Brook. It is presumed that at this spot, the fault returns to its former direction, and does not terminate, for the millstone grit is not restored at this point, though the limestone (*b*) is, but gradually appears further on (*c*).



a. Old red sandstone. *á.* Old red conglomerate. *b.* Carboniferous limestone. *c.* Millstone grit. *d.* Coal measures.

Though in one sense, the fault which exists near Ailberton may thus be

considered as continued into this great fault from the Leech Pool to beyond Denbigh Lodge, another description of continuation of it, is in the line or axis which runs into the coal-field through the successive points of acute flexure made by the different beds or "delves" of coal.

This flexure or irregular basin shape seems here moulded by the two unconformable dips of the old red, which the fault at Ailberton divides; but they seem to bend from one position to the other less abruptly, and with less dislocation of the strata, than near Ailberton.

It is suspected, however, that at the bend of the upper coal beds at Whitecroft, there is some little dislocation; and very possibly near Lydney, the Coleford High Delf does not bend so completely without dislocation, as it is represented to do in the map.

In that part of the line, where the fault runs nearly parallel to the strata on both sides, it has not been found possible to distinguish clearly one formation from the other, or consequently the exact line of dislocation. The characters of the millstone grit and old red are likewise not well defined.

A remarkably hard, fine-grained, purplish rock occurs, in white clay, at Old Croft, also at a spot further on in the Forest, and a similar rock appears near Bream. It sometimes contains quartz pebbles, and is possibly a variety of millstone grit. It has a slight mixture sometimes of calcareous matter; and limestone itself is here occasionally subordinate to the grit*. Its position, however, partakes somewhat of the obscurity, already mentioned, respecting this line of fault, from the Leech Pool near Lydney, to Old Croft in the Forest.

* At Clearwell Meend, near Coleford, the limestone is worked in two places in the millstone grit; and small pieces have been dug out at Old Croft bearing the red sandy appearance of that at Clearwell Meend.

Fig. 1

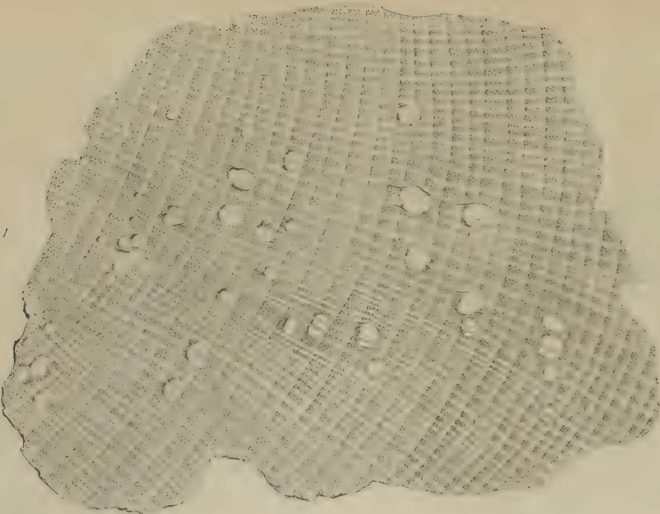


Fig. 2

Fig. 3

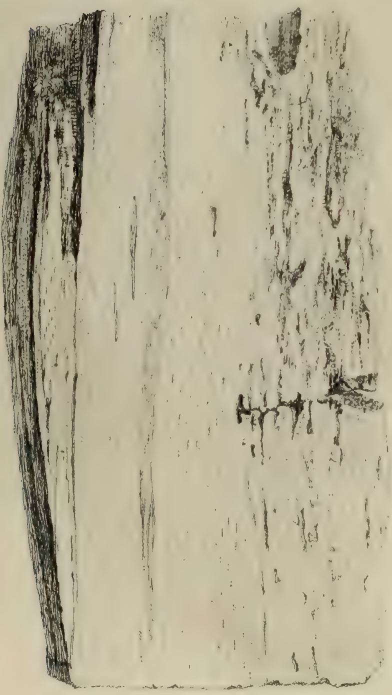


Fig. 4

Wood partially petrified, from a Roman Aqueduct in Lippe Buckeburg.
Fig. 1. Transsection nat. size p. 207. Fig. 2. Section of a petrif. part mag. 15 times.
Fig. 3. Long. section nat. size p. 243. Fig. 4. Section of d. mag. 10 times.

Fig. 1.

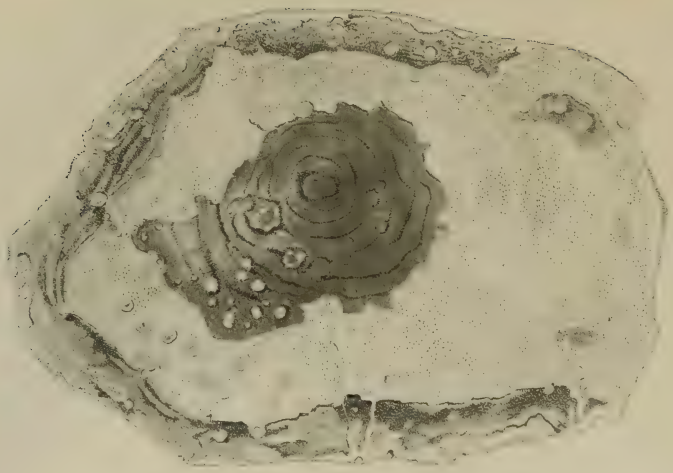


Fig. 2

Fossil Wood from Antigua p. 208.

Fig. 1. Natural size. Fig. 2. Portion magnified 6 times.

XVII.—*Notice respecting a Piece of Recent Wood partly petrified by Carbonate of Lime, with some Remarks on Fossil Woods.*

By CHARLES STOKES, Esq., F.G.S.

[Read June 8, 1836.]

THROUGH the kindness of Mr. Heuland I have lately received a collection of fossil woods from Germany, that gentleman having very obligingly engaged one of his correspondents to attend to the particular inquiries I wished to make, and to collect for me the objects described.

To this collection was added a specimen of recent wood in which some portions have become petrified by carbonate of lime; and although this is not the first known instance of the occurrence of wood partly petrified by calcareous spar, yet it has, from its peculiarity, led to comparisons with some other fossil woods of remarkable appearance, both calcareous and siliceous, and for which it appears to have afforded some explanation. I am induced to submit to the Geological Society the following observations respecting it, in the hope, that by exciting attention and remark from other observers, we may obtain some knowledge on the very difficult question of the process of petrification.

This piece of wood is of the common beech (*Fagus sylvatica*), and was found by M. Cotta of Tharand in an ancient Roman aqueduct at Eilsen in the principality of Lippe Buckeberg, but I understand that he has not published any account of it.

The size of the portion in my possession, is about $3\frac{1}{2}$ inches by $4\frac{1}{2}$, and the thickness is nearly one inch. For the better understanding of the description, the accompanying drawing has been made of the specimen (Plate XVI. fig. 1).

The wood is, for the most part, in the state of very old dry wood, but there are several insulated portions, in which the place of the wood has been taken by carbonate of lime. These portions, as seen on the surface of the horizontal section, are irregularly circular, varying in size, but are generally a little less or more than $\frac{1}{8}$ of an inch in diameter, and they run through the whole thickness of the specimen in separate, perpendicular columns.

The vessels of the wood are distinctly visible in the carbonate of lime, and

are more perfect in their form and size, in those parts of the specimen, than in that which remains unchanged; as if the petrification of those portions had taken place, while the wood was yet in sound condition, and the remaining part had since contracted around them, as it gradually decayed. This is shown by the bending of the medullary rays, adjoining the limits of the calcareous portions.

Dr. Turner has examined one of these portions, and finds it to contain 9 per cent. of ligneous fibre, the rest being carbonate of lime.

I have not obtained an account of the situation of the wood in the aqueduct, or of any circumstance to explain how it had become exposed to the action of water containing carbonate of lime in solution, but I am unwilling to delay the communication to the Geological Society, of the remarks it has suggested to me.

Mr. Robert Brown, to whom I had the pleasure of showing this specimen on the day I received it, immediately reminded me, of one of silicified wood from Antigua in my own collection, which we had formerly examined together, and in which the polished horizontal section exhibits a similar appearance of insulated portions, that have the structure preserved in a more perfect state than the rest of the specimen, as is represented in the accompanying drawing. (Pl. XVII).

The whole specimen is completely silicified, and takes an excellent polish. The portions best preserved are irregularly circular in form, about $\frac{1}{3}$ of an inch or rather more in diameter, and in them the vessels and medullary rays are distinctly seen in good condition, while in all the other parts (although the general form of the stem is preserved) the vessels are compressed (particularly round the more perfect portions) and the medullary rays are bent and comparatively indistinct.

From the different condition in which the different parts of the wood have been preserved, it appears, that the process of petrification had first taken place simultaneously at a number of separate points, and then had stopped, and that the unchanged part had subsequently in some degree decayed.

If at this period a transverse section of the wood had been made, its condition must have been similar to that of the wood from the Roman aqueduct, having some parts petrified while the greater portion was still in the state of wood, though not in a sound state. After this, the progress of petrifaction was again renewed, and the partially decayed remainder of the wood has been silicified.

Another instance (which is of calcareous petrification) appears also to have an analogy to the above-mentioned. This is the specimen from Allen Bank in Berwickshire, described and figured by Mr. Witham (On the Structure of Fossil Vegetables, Pl. VIII. fig. 7), under the name of *Anabathra pulcherrima*.

The texture of this plant, whatever it may have been, was much more lax than that of the woods before spoken of. The horizontal section shows some instances, in which the structure is preserved from the centre to the circum-

ference, but more frequently only insulated portions of about one tenth of an inch in diameter, in which also the structure is well preserved. The direction of the rays, which pass through these portions, shows that they are, with scarcely any exception, in the same position as when the stem was entire, although they are now surrounded by mineral matter (carbonate of lime), in which scarcely a trace of the structure of the plant remains.

From this condition of the fossil, it appears, that as in the former instances, the progress of petrifaction commenced at a number of separate points and was afterwards interrupted, but in the present case, the whole of the remaining portion of the wood appears to have been entirely destroyed by decay, which occurred after the interruption, and no renewal of the process took place, while any of the other parts of the wood existed.

The fossil wood from Linnel Braes, described and figured by the same author (Pl. 3.), is also a case where parts only of the wood have been petrified and the remainder entirely decomposed by subsequent decay, but the petrified parts are in their places, and the intervening space is filled up by crystallized carbonate of lime.

Such are the appearances shown by sections made in a transverse direction, or at right angles to the axis of the growth of the wood. In the examination by means of longitudinal sections, we shall find the following differences between them.

In the recent wood from the Roman aqueduct, the carbonate of lime runs, as I have stated, through the whole thickness of the specimen, the petrified portions appearing to be in long columns. In the Antigua specimen, the well preserved portions are not, in any of the instances I have seen, more than three eighths of an inch in the longitudinal section, and their form is irregular.

In the Allen Bank fossil, the insulated petrified portions are of the same size in the longitudinal as in the transverse sections, showing that they are of spherical form.

In the last named instances it appears to me, that we must conclude, that the whole of the wood was penetrated by a saturated solution of the mineral matter, and that the solution was in the state at which crystallization was about to commence. In solutions in such a state, we know that crystallization frequently begins simultaneously at a number of separate points, round which the crystalline matter continues to aggregate. In the Allen Bank fossil, at the external part of the section, this has evidently taken place, as an examination with a magnifying glass shows, that although the structure of the wood is preserved undisturbed, yet that the petrifaction is there made up by the contact of a number of small spheres. The progress of petrifaction, however, appears to have stopped before it had mineralized the whole of these specimens, and this may have been caused by an accession of water diluting the solution, below the point at which crystallization would go on. The variation in the quantity of rain falling at different periods, or in different seasons, might occasion such a result. After this, as I have before remarked, the unchanged portion of the wood was subject to decay. In the case of the Antigua specimen, before the process of petrifaction

was renewed, the wood had in some degree decayed and contracted; but in the Allen Bank fossil it had entirely decomposed and disappeared, leaving scarcely a trace of structure in the remaining parts. These are filled up with calcareous spar, which has crystallized from a number of separate points, and continued till the whole mass was united.

I must here advert to what I have mentioned, respecting the position of the insulated petrified portions of the Allen Bank fossil, in which the structure shows, that they are scarcely at all removed from the position in which they grew. As these seem to have remained in their places, after the other portions of the wood had decayed and disappeared, and before the intermediate parts had been filled up by solid mineral matter, it appears to follow that they must have been suspended in the fluid solution which has since crystallized around them,—a condition which it is certainly difficult to comprehend.

In regard to the piece of wood from the aqueduct, the petrified portions are also separate and insulated, but as they are in long continuous columns, it is probable that the whole of the wood was not equally penetrated with the calcareous solution.

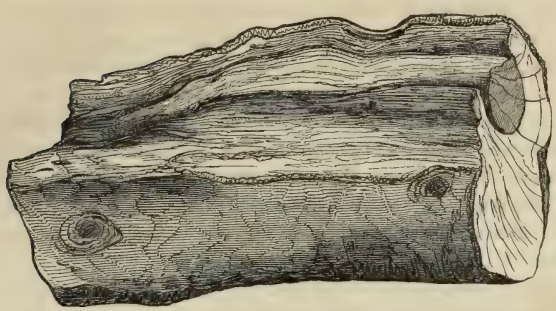
The other cases I have met with, of a partial petrifaction by carbonate of lime, are those of the hazel nuts at Belfast Lough, mentioned by Dr. Macdonnel, in 1810*, and of partly petrified wood and nuts, described by Mr. Phillips, from the vale of the Aire, near Ferry Bridge, in Yorkshire†. In this latter case, it appears that the wood and nuts are in a deposit of alluvium. Many pieces of the wood, and the kernels of some of the nuts, found at a depth of 12 feet, are partially petrified.

A specimen of the wood here mentioned, which was given by Mr. Phillips to Dr. Buckland, who has allowed me to examine it, is a portion of a stem or branch, split longitudinally, about four inches in length, and about two and a half in diameter. In this, a part near the centre, is now completely petrified by carbonate of lime. This portion is about half an inch in diameter at one end, and extends longitudinally through the wood to the length of about three inches, and terminates in a point. It is in its natural position, and the medullary rays are continuous through the calcareous part and the unchanged portion, as shown in the accompanying wood-cut.

The line of separation between the calcareous part and the unchanged wood, is perfectly well defined, and although we may suppose that the vessels of the wood, have acted as conductors to the solution, and given it a direction longitudinally through the stem, yet it is difficult to understand why the petrifaction has been confined to a single spot or column.

* Geological Transactions, First Series, vol. iv. p. 448.

† Philosophical Magazine and Annals of Philosophy, New Series, vol. iv., 1828.



Partially petrified wood from the Vale of the Aire, near Ferrybridge, Yorkshire.

It is indeed evident that the vessels of the wood have thus acted as conductors to the solution, from the sinuosities in the outline of the petrified portion which follow the irregular direction of the fibres, where they have by knots or other interruptions been forced from a straight line. The calcareous material was probably derived from the neighbouring limestone beds, and might be supposed to diffuse itself through the alluvium; but in the case of the aqueduct, we cannot imagine that there was so large or so generally diffused a supply of mineral matter. I should mention also, that the examination of thin slices with a microscope shows, that the structure is rather better preserved in the wood at Ferrybridge, than in that from the aqueduct.

Mr. Brown has also shown me specimens, in his possession, of petrified wood, in which the greater portion is silicified, but there are some parts still in a soft state, and not at all penetrated by the silex. Some of these are from Lough Neagh, and others from Bonn.

Although the amount of information obtained by the preceding observations is but small, yet, in establishing the facts, that petrifaction sometimes commences at a number of separate points, and that it is liable to be interrupted and again renewed after an interval of time, we have an explanation of the circumstances which have been difficult to understand, in regard to many specimens of fossil wood, in which parts of the ligneous structure are preserved in good condition, while other parts appear to be more or less decayed.

The same facts appear to occur both in siliceous and calcareous petrifactions; but nothing that I have met with, is calculated to throw any light upon the question, of the means by which the solution of siliceous matter has been accomplished.

A short description of the different conditions in which fossil wood appears in different specimens may be worthy of attention.

Sometimes the most minute parts of the structure have been preserved, as is shown under the microscope in the markings of the vessels of Palms, and the well known instances of the circular discs peculiar to the vessels of coni-

ferous wood, which are as distinct in the fossil as in the recent wood. From this high state of perfection, we have every degree of condition, down to the very last stages of decay ; hence it appears, that there is not anything in the state or condition of the wood, which has influence upon the process.

Sometimes we find petrifactions of the most close grained, and probably the hardest kinds of wood, in good condition ; at other times, we meet with stems of a soft and succulent character, and there are also instances of the complete silicification of the young leaves of a palm tree, when just about to shoot forth, and in that state which, in the West Indies, is called the cabbage of the palm.

The different states in which the stems of palm trees have been preserved, are also deserving of notice. These consist of a cellular tissue, among which are separate fascicles of ligneous vessels, which rise through the stem. In some few cases, the cellular tissue is well preserved, while scarcely any of the vessels or woody fibres remain, and the spaces they occupied, are now hollow passages through the specimen. In other cases, the cellular tissue has disappeared, and the bundles of vessels alone are well preserved. Other cases occur, in which both the cellular tissue and the vessels, are preserved in good condition. On these facts, I would remark, first, that where the cellular tissue has been petrified, and the vessels have disappeared, the process must have taken place, soon after the wood had been exposed to the action of moisture, because the cellular part would soon decay; and that it was then suspended, as in the cases described in the beginning of this paper. Secondly, where the woody vessels alone have been preserved, I conclude, that a time elapsed before the process of petrifaction commenced, during which the cellular tissue had decayed. Thirdly, that where both structures are preserved, the process had commenced at an early period, and continued without interruption till it was completed throughout.

There are also some cases, in which hollow dicotyledonous trees have been petrified, and in these cases the middle part is filled up with chalcedony and agates, sometimes leaving cavities which are coated with crystals of quartz. I have also seen cases, in which the cellular tissue only of the stems of palms has been preserved, and the structure of woody vessels had disappeared, but the places where they had been, have been filled up (doubtless subsequently) with agates.

In conclusion, I have only to state my regret, that the information I have to offer is so scanty, and to express the hope that this subject may be taken up by others, who have better opportunities, and more knowledge and talent for conducting the inquiry.

Further Notice on the partially petrified piece of Wood from an Ancient Roman Aqueduct in the Principality of Lippe Buckeberg.

[Read December 14, 1836.]

SINCE I communicated to the Geological Society, the preceding notice on the partly petrified wood from the ancient Roman aqueduct at Eilsen, in the principality of Lippe Buckeberg, Mr. Robert Brown has shown to me a specimen from the same piece of wood, which was presented to him at Tharand, in the month of October last, by M. Cotta of that place, who discovered the wood in the aqueduct, and remarked its peculiar condition. Mr. Brown has pointed out to me in the longitudinal section, that the petrified portions, in his specimen, are about two inches in length, and in the middle part, nearly a quarter of an inch in diameter, and terminate in a point at each end. The petrified portions are, in these instances, completely inclosed within and surrounded by the unchanged wood. See Pl. 16, fig. 3.

Mr. Brown has observed another remarkable circumstance in the condition of these petrified portions. The change of the longitudinal fibres appears to be complete, but the medullary rays, of which the ends are seen in this section, are still in their ligneous state, as shown in the magnified engraving, Pl. 16, fig. 4.

From this it appears, that the petrifying process had not been so fully completed, as in the portion of the same wood, which first came into my possession; but on referring to that specimen, I have found some instances, in which a part of the medullary ray, that passes through the petrified portion, has not been so completely changed as the surrounding longitudinal fibres, or the part of the same ray, which is more in the centre of the petrified portion.

Of the rest of this specimen, some part is much decayed and worm-eaten, while another part is hard and in good condition; and the line of separation between them, is, in some places, remarkably well defined.

Although the latter does not to the eye, present any appearance but that of sound wood, I was induced to examine it, and had the pleasure of finding, that, what may perhaps be considered as the first stage of petrifaction, has taken place in it.

I cut in a transverse direction as thin a piece as I could detach with a sharp knife, and placed it in water under the microscope, then adding with the point of a quill a drop of muriatic acid, I immediately perceived the disengagement of gas, which seemed to proceed chiefly from the inside of the larger vessels, as if an extremely thin coating of carbonate of lime had been deposited within them. In the more decayed part, there is also a slight action produced by the acid, but not so strong as in the sounder part.

From Dr. Buckland, I have received some specimens of fossil wood from Allesley, near Coventry, respecting which he has sent a communication to the Society*, and at his request, the Rev. W. Bree has also sent to me specimens from the same locality. Among these, which as far as I have been able to ascertain, are all coniferous woods, are several in which some portions are in a much better state of preservation than the rest of the specimens, although the whole is now silicified. These cases are analogous to that from Antigua, described in my former notice on this subject; but in that instance, the longitudinal section showed, that these better preserved portions were not more than three-eighths of an inch in length, and these were the longest I had then observed. In some of the Allesley specimens, these portions are full an inch in length, and terminate in a fine point at each end, in the same remarkable manner as I have above described to be the case, in the portion of the piece of wood from the Roman aqueduct belonging to Mr. Brown. In others, the best preserved portions are long narrow columns, going through the whole length of specimens, three inches long.

I have not much to offer in the way of remark, in addition to the simple description of facts above stated. The instances in which some parts of specimens of petrified wood, have the structure better preserved than the rest, are not uncommon; but in the detection of the commencement of a mineral deposition in the vessels of the wood, and in Mr. Brown's remark of the medullary rays remaining unchanged, while surrounded by the petrified longitudinal fibres, we have, I believe, the first ocular demonstration of progressive steps in the process of petrifaction.

Since the above was written, Mr. Arthur Aikin has obligingly communicated to me the following particulars of a piece of wood containing small particles of metallic copper.

"About twenty years or more ago, it was discovered that a bog near Dolgellau in Merionethshire, contained small lumps of greenish blue carbonate of copper. It appeared to some speculators in Liverpool, that a profit might be derived from cutting out the peat, burning it, and then smelting the ashes, in which, of course, the copper would be contained. In prosecuting this undertaking (which I believe was soon abandoned) small branches of oak and birch were met with, impregnated more or less with metallic copper. Of these two or three small specimens came into my possession.

"The copper probably came into the bog in the state of sulphate from the decomposition of copper pyrites in the face of some adjacent rock, and was carried thence into the bog by the rain. It must of necessity have entered the pores of the wood while in solution, and then have separated itself from its oxygen and acid, but by what agency is not very clear to me. Both tan and Gallic acid are very efficacious in reducing certain metallic oxids, and these two substances had probably some share in producing the appearances in question."

* Proceedings of Geological Society, No. 48, vol. ii. p. 439.

XVIII.—*Remarks on a Section of the Upper Lias and Marlstone of Yorkshire, showing the limited vertical range of the Species of Ammonites, and other Testacea, with their value as Geological Tests.*

By LOUIS HUNTON, Esq.

Communicated by J. F. Royle, Esq., F.G.S.

[Read May 25, 1836.]

On presenting a stratigraphical arrangement of the fossils in the lias formation on the coast of Yorkshire, I wish to offer the following remarks relative to their geological distribution.

The section (p. 221.) refers to that part of the coast between Whitby and Redcar, in which the Loftus and Boulby Alum Works are situated, and was named by General Mudge "Easington Heights." Its greatest elevation is 681 feet. It includes the inferior with a part of the great oolite series; and the lias is better developed in this place than in any other part of the coast, the upper shale having a thickness of 200 feet, and the marlstone of 160; and there are about 150 of the lower shale also exposed.

With regard to the correctness and universality of the order given to the fossils, the position of no one species was fixed till after several had been extracted from the situation indicated in the section, as well as in various different localities from the Alum Hills, fronting the vale of Thirsk, to the peak near Whitby; and in the majority of instances, from thousands of specimens afforded by the quarrying of the lias shale in the manufacture of alum. Though it would have been easy to have added many more species, the geological situation of which is determined, yet wherever the limits of distribution have not been clearly defined, they have been omitted.

Upper Lias Shale.—Commencing at the surface of this deposit, the first fossil present in any quantity, is the *Nucula ovum* (see section, p. 221.); which, after descending a few feet and entering what is technically called the "hard or cement stone seam," occurs in great abundance; but below that bed it

becomes gradually scarcer and smaller, so that after a descent of 60 feet, it is rarely met with, and I believe has never been found so low as the jet rock. The *Orbicula reflexa*, and the small, but delicate and beautiful *Plagiostoma pectenoideum* are associated with the Nucula, and similarly distributed. It may be worthy of observation, that the *Nucula ovum* is singularly characteristic of that portion of the upper shale used in the manufacture of alum, and that wherever the shale occurs without this shell, it has been found unfit for the remunerative production of the salt*. This is owing to the nature of the shale, the upper part, where calcined, being richest in sulphate of alumina; not, as might be supposed, from containing originally *more sulphur*, but a *less proportion*, the lower strata having such an excess of pyrites and bitumen, that the contents of a kiln made from such schistus, invariably overroasts. A large Pallustra, or Amphidesma, (the *Amphidesma donaciforme* of Phillips) is also plentiful in the upper part; but it is occasionally found in the lower, and a similar shell occurs in the Marlstone.

But of all organic remains, the Ammonites afford the most beautiful illustration of the subdivision of strata, for they appear to have been the least able, of all the Lias genera, to conform to a change of external circumstances. Of the species, most plentiful in the upper part, scarcely any are found in the lower; except a few doubtful individuals of *A. communis* (the prevailing species in the "hard seam") which are now and then seen so low as the jet rock; and though *A. fimbriatus* and *A. heterophyllus* are found in that stratum, they are always dwarfish, seldom attaining three inches in diameter, whereas in the upper beds, they are met with twenty inches in diameter.

The portion of the series mentioned before as the "Jet Rock," is a very compact and highly bituminous bed, from 20 to 30 feet thick and 150 feet below the surface of the formation. It contains many flattened, pyritous nodules, which generally inclose organic remains. The rock itself is also so very sulphureous, that when a small heap of it was calcined at the Loftus works some time ago, the melted bitumen and sulphur flowed in flaming streams. The whole of the jet used in the manufacture of ornaments, is extracted from this stratum; for when occasionally met with higher up, it is like coal in its fracture, and too brittle to work well; and in the inferior strata, as the marlstone, it forms merely a thin coat, enveloping a lump of fossil wood.

* The Alum Works, of which lias shale is characterized by the *Nucula ovum*, are the Peak, on the extreme east, and Stow Brow, Godeland Banks, Sandsend, Kettleness, Boulby, Loftus, Selby Hogg, and Osmotherly, on the extreme west. Failures have occurred to different works in attempting the calcination of the lower portions of the Upper Lias, or those strata undistinguished by the *N. ovum*.

The seams are sometimes 20 feet long by 6 feet broad, but they are often smaller, and their greatest thickness is 3 inches.

The Jet Rock is also peculiar for containing the remains of the Teleosaurus; for though Ichthyosauri and Plesiosauri appear pretty equally distributed through the upper shale, this (fluviatile?) reptile is rarely found but in, or immediately above, the Jet Rock. Its bones are generally scattered in separate nodules, the upper jaw being scarcely ever united to the lower. With the exception of the specimen in the Whitby Museum, I am not aware of any instance of this animal having been found entire, whereas the other saurians seldom want more than the head or paddles.

On inspection of the section, it will be perceived, that the Jet Rock has its peculiar suite of Ammonites, and here, as was before observed, *A. heterophyllus* and *A. fimbriatus* make their first appearance, being about the size of a half-crown, while in the "hard seam" they attain the enormous magnitude of 1 and 2 feet in diameter. The *Ammonites Crassulus*, (*n.s.*) common to the whole upper lias, on the other hand, has its greatest development in the Jet Rock, gradually diminishing from $1\frac{1}{2}$ inches to $\frac{1}{2}$ an inch in the overlying beds. An interesting, though perhaps it may appear trifling, circumstance attending this fossil is, that as it decreases in size it becomes more numerous, many hundreds being then found together.

The lowest bed of the upper shale is hard, compact and sandy, and is singular for its great barrenness of fossils, occurring as it does immediately beneath one so prolific as the Jet Rock. This scarcity, combined with the arenaceous nature of the stratum, may perhaps afford some hints for elucidating, hereafter, the anomaly of fluviatile reptiles being mixed up with pelagian shells and fishes. It is a plausible speculation, that during the formation of the upper lias, the bottom of the sea in which it was deposited, was gradually settling. This conjecture is supported, by the greater prevalence of vegetable matter and fluviatile (?) reptiles in the lower part, and the increase in number of the larger species of Ammonites, Nautili, and Belemnites in the upper. This conjecture is further supported by the mineralogical nature of the schistus, silex being more abundant in the inferior parts, and alumina in the superior, an arrangement which would naturally take place, if the coast during that epoch gradually sunk, and the land, the detritus of which afforded the material for the lias, as gradually receded; the finer argillaceous sediment being consequently carried into the deeper and more and more distant parts.

Marlstone.—On entering this series, we at once perceive a striking contrast to the upper lias, for independently of the decided mineralogical difference,

not only the species and genera, but the *order* of Testacea have undergone a total revolution. Instead of a preponderance of Cephalopods and a scarcity of bivalves, we now have an overwhelming majority of the latter, some of the beds being almost constituted of Cardia and Gryphytes, which have also an extensive vertical distribution. *Avicula Cygnipes*, *A. inæquivalvis* and *Pullastra antiqua* are equally abundant in the whole series; but other shells, as *Cardium truncatum*, occur more plentifully in the inferior strata, whilst *Terebratula triplicata* and *T. trilineata* crowd the superior.

The species of Ammonites, though few in number, are, however, highly characteristic; thus we find *A. vittatus* about the centre of the series, confined to a very small range, associated in nodules with the *Cardium multicostatum*, *Turbo undulatus*, and *Pecten planus*; but the two latter occur in other parts of the formation. The *A. maculatus*, is constantly found at the junction of the *marlstone* with the *lower lias*, which here pass so gradually into each other, that it is impossible to determine where the sandstones end and the blue shale begins. I have long sought for *A. maculatus* in the upper and central portions of the *marlstone*, but have never found it many feet above the junction beds; and though this and other Ammonites from unequal geographical distribution, may be more abundant in one place than in another (*A. maculatus* is in greatest number at Staithes, *A. Hawskerensis* at Hawskerbottoms), yet they constantly maintain an invariable relative position. *A. Hawskerensis* I believe to be also a junction Ammonite, but from its rarity in other situations, than that mentioned, it is not entered in the table.

The above description may not, in some instances, exactly accord with previous statements, but one great source of error has hitherto been, the collecting of specimens from the debris of the whole formation, accumulated at the foot of cliffs or other similar situations, where they have long laid, and the inferring of their position from the nature of the matrix. A strong temptation to this method arises from the facility it affords of obtaining finer fossils than can possibly be procured from newly quarried nodules, the hard nature of which renders it very difficult to extract the fossil entire, without long exposure to air and moisture.

Annexed is a systematic list of the fossils found in the upper lias and marlstone, and noticed in the section.

List of Fossils found in the Upper Lias and Marlstone*.

Genus. Species.	Reference.	Formation.
Ophiura Milleri	Phill. T. xiii. fig. 20†	Marlstone.
Pholadomya obliquata	Phill. T. xiii. fig. 15	———
——— ambigua (Lutraria Y. & B.)	Sowerby‡, Y. & B. T. viii. fig. 4§	———
Amphidesma? donaciforme	Phill. T. xii. fig. 5	Upper lias.
——— rotundatum	Phill. T. xii. fig. 6	———
Pullastra antiqua	Phill. T. xiii. fig. 16	Marlstone.
Cardium truncatum	Sowerby, Phill. T. xiii. fig. 14	———
——— multicostatum	Phill. T. xiii. fig. 21	———
Nucula ovum	Sowerby, Phill. T. xii. fig. 4	Upper lias.
Modiola scalprum	Sowerby, Phill. T. xiv. fig. 2	Marlstone.
Inoceramus dubius	Sowerby, Phill. T. xii. fig. 14	Upper lias.
Avicula cygnipes	Phill. T. xiv. fig. 3. Pecten Y. & B. Pl. ix. fig. 3	Marlstone.
——— inæquivalvis	Sowerby, Phill. T. xiv. fig. 4	———
Plagiostoma pectenoïdeum	Sowerby, Phill. T. xii. fig. 13	Upper lias.
——— Hermanni	Voltz	Marlstone.
Pecten æquivalvis	Sowerby, T. cxxxvi.	———
——— sublævis	Y. & B. Pl. ix. fig. 9. Phill. T. xiv. fig. 5	———
Gryphea depressa	Phill. T. xiv. fig. 7	———
Terebratula acuta	Sowerby, Phill. T. xiii. fig. 25	———
——— bidens	Phill. T. xiii. fig. 24.	———
——— compressa?	Y. & B. T. viii. fig. 14	———
——— tetrædra	Sowerby, T. lxxxiii. fig. 4	———
——— trilineata	Y. & B. T. viii. fig. 17	———
——— triplicata	Phill. T. xiii. fig. 22	———
Orbicula reflexa	Sowerby, T. dvi. fig. 1	Upper lias.
Dentalium giganteum	Phill. T. xiv. fig. 8	Marlstone.
Turbo undulatus	Phill. T. xiii. fig. 18	———
Belemnites compressus	De Blainville‖, Phill. T. xii. fig. 21	Upper lias.
——— elongatus	Miller¶, Y. & B. Pl. xv. fig. 1	———
——— trifidus	Voltz**	———
Nautilus astacoides	Y. & B. T. xiii. fig. 2	Upper lias.
Ammonites angulatus	Sowerby, T. cvii	———
——— annulatus	Sowerby, T. ccxxii	———
——— Boulbiensis	Y. & B. p. 267	———
——— communis	Sowerby, T. cvii. fig. 2. Y. & B. Pl. xii. fig. 3	———
——— concavus	Sowerby, T. xciv. low. fig.	———

* In the table, those species only are enumerated of which figures have been published. Where two references are given, the first is to the author who named the fossil; the second to the work in which a Yorkshire specimen is figured.

† Phillips, Illust. Geol. Yorkshire, part i. 1829. ‡ Sowerby, Mineral Conchology, 1812—1829.

§ Young and Bird, Geol. Survey of Yorkshire Coast, 2nd edition, 1828.

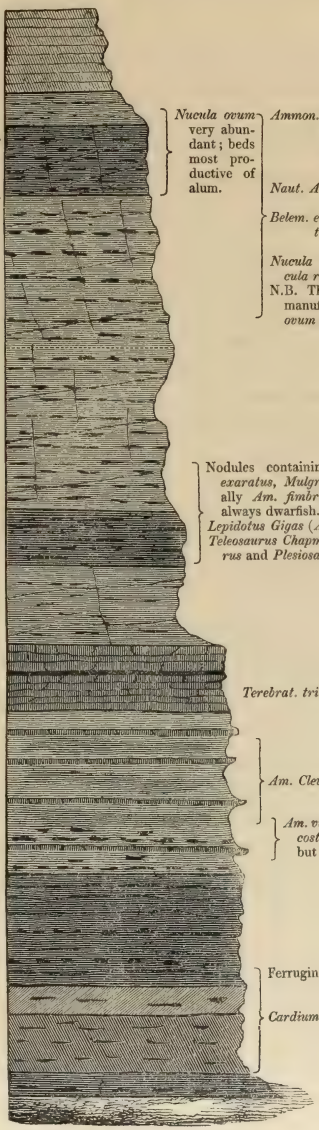
‖ Mémoires sur les Belemnites, 1827. ¶ Observations on Belemnites, Geol. Tr. 2d Ser. vol. ii.

** Observations sur les Belemnites, 1830.

Genus. Species.	Reference.	Formation.
Ammonites crassus	Phill. T. xii. fig. 15, tuberculated var	Upper lias.
—— elegantulus	Y & B. p. 267 (? elegans Phillips, but not Min. Con.)	——
—— exaratus	Y. & B. Phill. T. xiii. fig. 7	——
—— fibulatus	Sowerby, T. cccevii. fig. 2	——
—— fimbriatus	Sowerby, (cornucopia) Y. & B. T. xii. fig. 8	——
—— heterophyllus	Sowerby, T. cclxvi	——
—— Lythensis	Y. & B. p. 267. Phill. T. xiii. fig. 6	——
—— Mulgravius	Y. & B. T. xiii. fig. 8	——
—— ovatus	Y. & B. xiii. fig. 4. Phill. T. xiii. fig. 10	——
—— sigmifer	Phill. T. xiii. fig. 4	——
—— subarmatus	Sowerby, T. cccevii. fig. 1	——
—— subcarinatus	Y. & B. Phill. T. xiii. fig. 3	——
—— Walcotii	Sowerby, T. cvi. Y. & B. xii. fig. 1	——
—— Clevelandicus	Y. & B. T. xiii. fig. 7	Marlstone.
—— maculatus	Y. & B. xiv. fig. 9. Phill. T. xiii. fig. 11	——
—— vittatus	Y. & B. T. xiv. fig. 11. Ph. T. xiii. fig. 1 variety	——
Lepidotus gigas	Agassiz*	Upper lias.
Ichthyosaurus communis	Conybeare† and De la Beche	——
—— platyodon	Conybeare and De la Beche	——
Plesiosaurus	Conybeare‡	——
Teleosaurus Chapmanni	Y. & B. Pl. xvi. fig. 1	——

* Recherches sur les Poissons Fossiles. † Geol. Trans. 1st Ser. vol. v. 2nd Ser. vol. i.
‡ Geol. Trans. 1st Ser. vol. v. 2nd Ser. vol. i.

Section of the Upper Lias and Marlstone at Rockliff, near Whitby (Easington Heights, Mudge's Survey), showing the limited Distribution of certain Species of Testacea, and the Order Cephalopoda in particular, Local Dip S.W. One Foot in Ten Feet.



Sandstone beds, containing plant seams .....

Inferior oolite .....

Shale, 10 feet .....

HARD or CEMENT-STONE SEAM. Numerous calcareous nodules, exclusively manufactured into Roman cement, 25 feet...

Nodules in these and succeeding beds highly ferruginous, occasionally been smelted at Newcastle .....

Lowest level worked for alum, 90 feet from the surface...

150 feet

JET ROCK. Many pyritous nodules, very much flattened, 20 feet.....

Hard compact shale, very sandy; a few small nodules. Very barren in fossils, 30 ft.

MAIN IRONSTONE BANDS, Connected blocks of hard ironstone, a foot and upwards in thickness, with thin seams of shale intervening, 25 feet...

Sandy shale, 5 feet .....

Iron dogger .....

Sandy shale, 10 feet.....

Iron dogger .....

Sandy shale, 15 feet.....

Iron dogger .....

Sandy shale, 18 feet.....

Iron dogger .....

Shaley sandstone, 10 feet.....

Alternations of calcareous sandstone and sandy shale, generally one sandstone bed alternating with another similar bed; the seams covered with fossils, 40 feet .....

Shaley marlstone .....

Shaley sandstone, gradually partaking of the nature of the lower lias shale, 20 feet

LOWER LIAS SHALE, 150 feet above the level of the sea .....

Nucula ovum very abundant; beds most productive of alum. — *Ammon. communis, Walcottii, subcarinatus. angulatus, crassus, fibulatus. subarmatus, Lythensis, Boulbiensis. annulatus, heterophyllus, fimbriatus.*

Naut. Astacoides.

Belem. elongatus. trifidus, with many undescribed species.

Nucula ovum, Plagiostoma pectenoïdeum, Orbicula reflexa.

N.B. The only portion of the shale used in manufacturing alum is that in which *Nucula ovum* occurs.

Ammon. crassulus, Ichthyosaurus platydon, I. communis, with Saurian bones of various genera and species. *Am. heterophyllus* and *fimbriatus, Belem. compressus*, with *Amphidesma donaciforme* and *A. rotundatum* (Phillips), all in greatest perfection and number in the upper part, gradually diminishing in quantity downwards.

Nodules containing *Ammon. sigmifer, elegantulus, exaratus, Mulgravius, concavus, ovatus*; occasionally *Am. fimbriatus* and *Heterophyllus*, though always dwarfish. *Lepidotus Gigas (Agas.)*; rarely met with elsewhere. *Teleosaurus Chapmanni*, with remains of *Ichthyosaurus* and *Plesiosaurus*, generally in pyritous nodules. — *Inoceramus dubius* and an undescribed Belem.

Terebrat. trilineata, very abundant.

Am. Clevelandicus.

Am. vittatus in nodules, with *Card. multicostatum. Pecten. planus* rarely occurs but in this position.

Ferruginous shell seams, with *Am. maculatus.*

Cardium proximum (new species).

Ophiura Milleri, Belem. angulatus, crassiusculus, Turbo turritus, Pholadomya obliquata, Modiola scalprum, Belemnite, n.s., *Plagiostoma Hermanni, Pullastra crassa, Pholadomya (undigna* Y. & B.).

Avicula cygnipes and *inequivalvis, Pecten subtilis* and *aequivalvis, Pullastra antiqua, Turbo undulatus, Gryphea depressa, (Donacitum gigauteum, Cardium truncatum* chiefly in lower part), *Terebratula tetraedra, compressa, triplicata,* and *bidens, Belem.*, n.s., *Terebratula acuta.*

XIX.—*On the Distribution of Fossil Remains on the Yorkshire Coast, from the Lower Lias to the Bath Oolite inclusive.**

By W. C. WILLIAMSON, Esq.,

(CURATOR OF THE MANCHESTER SOCIETY OF NATURAL HISTORY.)

[Read May 7, 1834, and November 2, 1836.]

THE formations noticed in the following pages are the lias, the inferior oolite, the lower carboniferous series of Smith, and the Bath or great oolite.

Lias.

The lias series on the north-east coast of Yorkshire, occupies a range of lofty cliffs, varying from 100 to 600 feet in height, and extending with little interruption from the Peak Hill, near Robin Hood's Bay, to the village of Saltburn, near Redcar.

It is separable into three great divisions, 1st. the lower lias, 2nd. the marlstone, and 3rd. the upper lias or alum shale.

1. *Lower Lias.*—On no part of the coast is the whole of this division exhibited, or has its depth been ascertained. At the base of Rockcliff, near Staithes, it has a considerable thickness, and at Peak Hill, a section of about 300 feet is exposed. It is probable, however, that its vertical dimensions are much greater, as blue clay is brought up by ships' anchors at a considerable distance from the shore; and as *Trochus Anglicus* with some other fossils, is found only among the shingle, generally much water-worn, and apparently washed up from submarine strata.

At present, nothing is known of the fossils contained in those inferior beds. In the exposed portion, the marl, in the lower strata, is compact, arenaceous, and generally of a dull blue colour, whilst in the upper it is more shaly. The fossils are thinly scattered, and few in species. On the scar at Robin Hood's Bay, near the lowest known part, occurs *Gryphæa incurva*, and a little higher *Gryphæa Machullochi*, both in great abundance; and associated with the latter, is sometimes found *Gryphæa depressa*.

A little above this bed is a seam which also contains organic remains, the most common, being *Hippopodium ponderosum*, *Pholadomya ambigua*, *Pholadomya*

* In this memoir two papers are embodied, one, on the distribution of Lias Fossils, on the Yorkshire coast, read May 7th, 1834: the other, on the distribution of Oolitic Fossils, read Nov. 2, 1836.

Murchisoni, and *Pinna folium*. They are found at Robin Hood's Bay, and near low water mark, under the heights of Rockcliff. At the former locality the Hippopodium preponderates, and at the latter the two species of Pholadomya. The Pinna, which occurs at both places, is sometimes obtained of a very large size, and one which I measured at Rockcliff was two feet in length; but, as is usually the case with this fossil, it was so crushed that it could not be preserved.

Towards the lower part and about the middle of this division of the lias, are found *Ammonites planicosta*, with fragments of *Pentacrinus Briareus* and *P. vulgaris*, (*P. caput Medusæ*, Miller), principally broken columns, which are very numerous, particularly at Robin Hood's Bay. Still higher in the series, and towards the top of the sandy strata, I have procured *Ammonites cornucopia*, *A. Turneri*, and *A. geometricus*, especially opposite the Boulby Alum Works; but I am rather undecided respecting these fossils, as they are rare. The strata next in succession are softer, and separated by seams of irony nodules, having below them at Robin Hood's Bay and Skinningrave, a bed which contains the little *Plicatula spinosa*. Towards the top of the lower lias rock, *Belemnites compressus* occurs, though not very plentifully. I found it principally at Boulby, where the highest beds are well exposed,

2. *Marlstone*.—The next series of beds belongs to the division called the Marlstone; and has an average thickness of about 130 feet. The first hundred feet are composed of alternating sandy and shaly seams, and the next or upper thirty of sandy shales, divided by bands of argillaceous, irony nodules, which are sometimes united in solid strata, 6 inches thick.

Towards the lower part of the division *Cardium truncatum* is very plentiful, especially near Staithes. An interesting fact is connected with this shell. The specimens which have both valves united, are found distinct from those with the valves separated; in the former the casts of the ligaments are preserved, but in the latter they are wanting.

In the sandstone seams towards the middle and lower part of the series, are found the following fossils in great numbers and confusion.

Ophiura Milleri, *O. loricata*, *Asterias Murchisoni*, nob. in Mag. Nat. Hist., *Cidaris*, with smooth spines, *Dentalium giganteum*, *Belemnites elongatus*, *Plagiostoma læviusculum*, *Modiola scalprum*, *M. Hillana*, *Avicula inæquivalvis*, *Gryphæa Bullata?* *Ostrea*.

Of these, *Ophiura Milleri*, *O. loricata*, *Asterias Murchisoni*, *Plagiostoma læviusculum*, *Modiola scalprum*, and the Cidaris are the most rare; the others, especially the Ostrea and Avicula, form immense masses, almost entirely composed of compressed and broken shells.

This portion of the stratum is best examined on the shore between Staithes

and Saltburn, where large blocks of the sandstone have fallen from the cliffs.

Above these sandstones is a layer of detached, irony and calcareous nodules, very rich in fossils ; the principal being, *Ammonites Clevelandicus, A. Stokesii, Turbo undulatus, Isocardia lineata, Cardium multicostatum, Corbula cardioides, Amphidesma recurvum, Mya V. Scripta, M. literata, Terebratula bidens, T. subrotunda, T. tetraedra, T. triplicata.*

Of these, *Ammonites Clevelandicus*, *Cardium multicostatum*, *Isocardia lineata*, and *Terebratula tetraedra*, appear to be the most abundant.

Eight or ten feet higher, is a series of beds from twelve to fourteen feet thick, consisting of arenaceous, blue shales, divided by bands of ironstone. The shales are filled with a profusion of fossils in a fine state of preservation, but difficult to extract, owing to the fragile nature of the shell, which is easily separated from the cast. The following is a list of the species : *Pecten æquivalvis, P. sublævis, Avicula cygnipes, A. inæquivalvis,* and *Plicatula spinosa* ; also two species of *Belemnites.*

The principal locality for these fossils, is under the signal cliff at Staithes, where the shales are near the beach and better exposed than elsewhere.

In the uppermost bed of ironstone, dividing the marlstone from the upper alum shale, the *Ammonites Hawskerensis* is found, at the south point of Runswick Bay, and associated with it, at Skinningrave, is a small fossil, apparently a *Trochus.*

3. *Upper Lias* or *Alum Shale.*—This division consists of three very distinct deposits, which are extremely persistent.

a. Lowest part, soft shale ..... 15 to 20 feet.
b. Hard shale, differing from the preceding in being much more tenacious, and in the laminæ breaking into larger fragments, about 30
c. Shale resembling the lowest part, being soft and rubbly, and breaking into very small fragments, average thickness about..... 130

Though well distinguished by lithological structure, these deposits are much better characterized by their fossils.

(*a.*) Near the junction of this deposit with the marlstone, *Belemnites compressus* occurs in considerable numbers, in a thin layer, especially at Runswick Bay ; and at the top, almost immediately below the hard seam (*b*), is a layer of argillaceous nodules, which is first seen about a mile north of the village of Staithes, and again under the cliffs at Lyth. At these places the shale, on the Scar, is completely studded, for forty or fifty yards, with round concretions, each containing either one or two *Ammonites annulatus,* or the alveo-

lus of a *Belemnites compressus*, the solid portion projecting from the nodule, and resting in the shale. The number of these fossils forms a remarkable feature.

(*b*.) About the upper part of this deposit occurs *Belemnites tubularis*, which is almost universally depressed at the smaller extremity, indicating apparently, that it was thin and delicate. It forms a regular but thin layer, a few inches above or below which it has not been noticed. I have seen it only on the Scar, a little to the south of Whitby, where *Belemnites compressus* is also found. The top of this deposit is occupied by numbers of *Ammonites elegans*, and *Inoceramus dubius*, the former being almost always depressed and as thin as paper; and both it and the Inoceramus are beautifully coated with iron pyrites.

Throughout the greater part of these shale beds, the fine hard jet, so valuable for manufacturing ornaments, is found in lenticular seams, from half an inch to three inches thick. It is obtained in quantity only in this deposit, which is called by the workmen the "Jet Seam."

Towards the middle and upper parts of the seam, large fragments of bituminized, coniferous wood occur, some of them weighing nearly a hundred pounds.

(*c*.) This division is by far the most interesting of the three, in its fossil contents.

Near the lowest part are immense numbers of spherical nodules, all strongly charged with sulphuret of iron. They vary in size from a small nut to six or eight feet in circumference, and often contain *Ammonites exaratus*, and *A. elegans*. These nodules are well exposed between Staithes and Runswick.

A little higher is a bed in which numbers of *Nucula ovum* occur. This fossil is generally diffused through the upper part of the series, but more particularly in this portion. Associated with it, and sometimes even attached to it, is found *Orbicula reflexa*. A very small variety of *Avicula inæquivalvis* is met with in the same stratum.

In all the lower portions of this division, (the one from which alum is procured) the remains of Saurians have been found; and some of the specimens obtained from it ornament the museums of Scarborough, Whitby, and Mr. Witham, of Lartington.

As yet, I believe only one species of the *Teleosaurus* and one of *Plesiosaurus* have been discovered, but two, and probably more, of *Ichthyosaurus*. One of them corresponds with *I. tenuirostris*, and the other must have been an immense species, as I have seen a lower jaw which is seven feet in length, and has many of the teeth preserved, some nearly three inches long.

The *Plesiosaurus* varies in size, but from a comparison of detached bones

with those of more complete specimens, the animal appears to have averaged from fifteen to twenty feet in length. The large specimen in the Scarborough museum would measure, if complete, at least eighteen feet. Its general characters resemble those of the *Plesiosaurus* common in the lias of Dorset. The *Teleosaurus Chapmanni* is sometimes found with the remains of the bony plates or scales attached, as in the splendid Whitby specimen, and some fragments in the Scarborough museum. It is rarely obtained with a perfect snout, the dilated extremity* being generally broken off.

Above the beds containing these remains, the large and beautiful *Nautilus astacoides* and *Ammonites Heterophyllus* occur in argillaceous nodules. When slit, they present beautifully the internal generic distinction, the chambers being generally filled with calcareous spar, and the siphuncle with only lias shale. The surrounding nodules, in some rare instances, are composed of sulphuret of iron. In this portion of the series, large fragments of bituminized, coniferous wood are very common, having occasionally a thin coating of jet. From thirty to sixty feet above these strata, *Ammonites Walcotti* and *A. ovatus* occur, both in the shale and argillaceous nodules.

At the Peak Hill, near the top of the upper alum shale, *Trigonia literata* and *Ammonites crassus* are found in a thin layer. The latter is remarkable for the thickness of its whorls, and the frequent decomposition of those which constituted the centre of the shell.

A little above these strata, *Ammonites communis*, and *A. fibulatus* are invariably found in small nodules, especially at the Peak to the south, and at Hawsker, to the north of Robin Hood's Bay. At both places the upper portion of the stratum is seen to great advantage as it descends to the Scar. At the Peak, imperfect remains of an *Astacus* occur in the same layer of nodules, but generally so crushed that its character is indeterminable.

The top of this shale at the Peak Hill, appears to contain *Ammonites striatulus*, enclosed in indurated calcareous masses ; and I am not aware of its having been met with at any other locality. It occurs so near the top that doubts are entertained whether it belongs to the alum shale, or to the overlying inferior oolite.

Inferior Oolite.

The subdivisions of this formation next come under our notice. They are best seen at Blue Wick, which presents the following ascending section :

a. Thick beds of dark grey, finely grained sandstone ..... 20 feet.
b. Irregular beds of yellow sandstone 20

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* See Buckland's Bridgewater Treatise, Pl. 5.

c. Hard ironshot sandstone	$1\frac{1}{2}$ feet.
d. Irregular beds of yellow sandstone, in some parts ironshot	30
e. Hard ironstone	4
f. Hard ironstone	8

(*a.*) At the bottom of this bed, we find a number of argillo-calcareous nodules, resembling those in the upper alum shale, and containing *Ammonites striatulus, Ammonites,* (a new species), *Orbicula reflexa, Lingula Beanii, Terebratula bidens,* and *Avicula echinata?* These fossils are chiefly obtained at Blue Wick. No other organic remains occur until within ten feet from the top of this division of the formation, where a layer of small nodules is met with, enclosing *Astacus rostratus,* and a new and larger species which has also been found in the clay of the cornbrash. A beautiful specimen of an antenna is in the Scarborough Museum. A little higher in the series is a thin but extremely characteristic seam of *Vermetus compressus,* also obtained in the coralline or Oxford oolite.

(*b.*) Proceeding upwards, we arrive at the series of irregular layers of soft yellow sandstone, throughout the whole of which small fragments of dicotyledonous? wood, and a species of Belemnites are rather numerous. Towards the top I have found, though rarely, *Mya literata,* and still higher, two species of Ammonites, one of which resembles *A. concavus,* which also exists in the upper lias. The other is a new species, which I have named *A. inornatus.*

(*c.*) The next bed, a hard ironstone, contains numerous, small, grey pebbles, also the same Belemnites as in the seam below, and is characterized by a great abundance of *Terebratula trilineata.*

(*d.*) The beds of yellow sandstone, occasionally charged with oxide of iron, enclose, within a few feet from the bottom, two seams about four inches each, of small pebbles, and at the top is found the same Belemnites as in the beds *b* and *c* though sparingly scattered; the shell resembling *Avicula echinata* is mingled irregularly with the pebbles.

(*e.*) From the hard ironstone bed, though only four feet thick, are obtained the greater portion of the fossils characteristic of the inferior oolite on the Yorkshire coast. The following is a list of the principal species, which chiefly occupy the middle and lower parts:

Trochus granulatus.	Auricula Sedgvici.
——— bisertus.	Nerita costata.
——— pyramidalis.	Turbo lævigatus.
Solarium calix.	—— funiculatus.
Actæon humeralis.	Rostellaria composita.

Natica adducta.
——— tumidula.
Ostrea Marshii.
—— solitaria.
Astarte elegans.
——— minima.
Modiola pulchra.
——— cuneata.
Mytilus sublævis.
Cardita similis.
Pecten virguliferus.
—— abjectus.
Trigonia angulata.
——— costata.
——— striata.
——— gibbosa.
Avicula Braamburiensis.
Nucula axiniformis.
Isocardia concentrica.
Cardium incertum.
Pholadomya ovalis.
Unio abductus.
Gastrochæna tortuosa.

Towards the upper part, are found,

Turritella muricata.
——— quadrivittata.
——— humifusa.
Terebratula obsoleta.
Caryophyllia convexa.

whilst the top of the seam is characterized by *Turritella cingenda, Melania Heddingtonensis,* and *Terebratula obsoleta.*

(*f.*) The highest beds of the inferior oolite consist of seven or eight feet of hard ferruginous sandstone, and are apparently destitute of fossils.

The *Ammonites striatulus, Lingulus Beanii, Orbicula reflexa, Terebratula bidens,* and the *Avicula echinata* sometimes occur in one mass in the lowest bed (*a.*). The *Lingula* and *Orbicula* are always found together, but the *Ammonites* are more frequently in masses by themselves. The *Avicula* and *Terebratula bidens* are very rare.

The characteristic fossils of this stratum are given by Professor Phillips in his Geology of Yorkshire, and the list continues correct.

Lower Carboniferous Series of Smith.

With the exception of the upper sandstone and shale, the divisions of this series are the most irregular of any on the Yorkshire coast. I have, however, taken sections at nearly every point where the series occurs, and I have been guided in my details by those which appeared the most striking and uniform. The best defined and least irregular are at the elevated cliffs between Cloughton Wyke and Blue Wick, where the whole of the series is well exposed; and where the upper and middle beds, containing the greater portion of the fossil vegetables, are alone visible.

The following section is in ascending order:

(*a.*) Immediately above the inferior oolite, is a black carbonaceous shale, containing no vegetable impressions; about ..... 10 feet.

(*b.*) Ironstone, containing a large species of Calamites, fronds of *Zamia gigas*, and remains of a remarkable fossil, apparently connected with the fructification of a Cycas ..... 20 feet.
(*c.*) Hard, pale, gritty sandstone 20
(*d.*) Shale 10
(*e.*) Gritty sandstone resembling the bed *c* 20
(*f.*) Soft yellow sandstone, containing stems of *Equisetum columnare* in a vertical position, with their roots downwards 8

[The opinions respecting these stems being deposited perpendicularly, are various; but that given by Professor Phillips, and urged by Mr. De la Beche in his Geological Manual, appears to me the most probable; viz.—that the plants were transported to their present positions, and deposited with their roots downwards, in consequence of the greater specific gravity generally possessed by the roots of this class of plants. The upper extremities being all broken off, afford rather a strong proof of their having been exposed to the action of disturbed water. We should expect to find the same effect produced upon the delicate vascular Equisetæ of the present day.

The place whence they have been transported, cannot however have been far distant, or they would have been still more disjointed and compressed; on the contrary, they often retain all their original roundness.]

(*g.*) Black shale ..... 3 feet.
(*h.*) Sandstones and shales of varying thicknesses. The sandstones are hard, fissile, and used as flags; total thickness about 170
(*i.*) Resting upon this series is another group of sandstones and shales; divided as follows:—

The lowest part, dark shaly sandstone	8 feet.
Harder, gray sandstone	6
Laminated sandstone, which contains numerous remains of beautiful ferns and cycadean plants	6
	20

The following is a list of plants obtained from the group:

Equisetum laterale.	Pterophyllum pectinoïdes.
Lycopodites Williamsonis.	——— minus.
——— falcatus.	Zamia lanceolata.
Thuytes expansus.	Otopteris acuminata.
Sphenopteris? longifolia.	Cyclopteris digitata.
——— hymenophylloïdes.	Tæniopteris vittata.
Neuropteris ligata.	Solenites Murrayana.
Pecopteris curtata.	Tympanophora racemosa.
——— Whitbiensis.	——— simplex.
——— Williamsonis.	Seeds of a Cycadites*.

The superior strata of inferior oolite composed of about 170 feet of sandstone and shale, con-

* Towards the lower part, it also contains thin seams of jet, of a quality inferior to that procured from the lias.

tain no remains of well defined plants; but near the centre of the series is a seam of inferior coal, about a foot in thickness, which is worked at Cloughton, but only for burning in limekilns.

The plants of this lower series of carboniferous shale, except when found in ironstone, are far from being so beautiful and well preserved as those in the upper shales; from which they also differ in the greater abundance of *Pterophyllum minus*, *Otopteris acuminata*, *Sphenopteris hymenophylloïdes*, and the deeply lobed variety of *Cyclopteris digitata*, and are apparently characterised by *Pterophyllum pectinoïdes*, *Equisetum laterale*, *Zamia lanceolata*, and the *Tympanophora* of Lindley and Hutton.

The thick beds of sandstone may be readily traced along the shore, but the other portions are very variable. The sandstones are generally micaceous and hard, but split readily, and are extensively used as flags. As building stones they are much inferior to many of the beds above the great oolite.

We will now proceed to describe

The Great or Bath Oolite.

The lithological characters or fossils of this formation vary very little to the north of the White Nab, near Scarborough, but to the south, a striking change occurs, which will be described in its proper place. We will first examine the sections at Cloughton Wyke, and the White Nab, where the great oolite presents the following general arrangement.

a.	The lowest bed, a hard blue limestone	14 to 20 feet.
b.	Hard, blue, fine-grained oolite, sometimes ironshot ..	6
c.	Hard, blue clay, often much tinged with iron	2
d.	Nodular ironstone, six inches to	1 foot.
e.	Clay	1
f.	Layers of nodular ironstone and argillaceous oolite ..	3 feet.

(*a.*) No fossils have yet been discovered in the lower and middle portions of this division, but towards the upper, I have found a species of *Ostrea*, *Amphidesma decurtatum*, *Mya calceiformis*, and an undescribed Ammonite; and the top of this bed contains *Belemnites compressus*, *B. Aalensis*, *Melania Heddingtonensis*, *Amphidesma decurtatum*, *Serpulæ*; and in a layer between this bed (*a*) and the hard blue, fine grained oolite (*b*), are found large tuberculated spines of a Cidaris.

Of the Belemnites, the species which I consider to be the *B. compressus* of Sowerby, not Voltz, is occasionally twenty inches in length, and about two in diameter; and the diameter of the other, *B. Aalensis*, is three inches, but the length is not more than seven. The spines of the Cidaris are sometimes five inches long, and about the diameter of an ordinary goose quill. Though they are not rare, I have found no traces of the Cidaris itself.

(*b.*) This bed is apparently destitute of organic remains.

(*c.*) The following fossils have been found in this stratum, chiefly at Cloughton :

Rostellaria composita.	Gervillia acuta.
Actæon glaber.	Cucullea cancellata.
Terebra vetusta.	Astarte minima.
Phasianella cincta.	Cardita similis.
Trochus.	Pholadomya acuticostata.
Avicula Braamburiensis.	Plesiosaurus.

Of the Plesiosaurus, we have remains of only one animal, which was found by my father near Scarborough, in 1825.

To judge from the size of the humerus and femur, the creature was twelve or fourteen feet long. The bones which have been obtained, consisting of the humerus, femur, vertebræ, and phalanges, differ but little from those of the *Plesiosaurus Dolichodeirus* of Whitby and Dorsetshire. The humerus, however, at its flattened extremity, expands equally on each side like the *femur* of *P. Dolichodeirus*. Two detached teeth have been found, which, if they really belonged to this animal, will prove a strong character in distinguishing the species. They are about an inch in length, nearly smooth, and very much resemble those of the crocodile.

(*d.*) The nodules of ironstone sometimes contain specimens of *Ammonites Blagdeni*. In this seam a mass of extraordinary bones was found, at the White Nab, near Scarborough. Two of the bones agree in form with those represented in fig. 4 and 5, of Mr. Mantell's "Illustrations of Tilgate Forest," and supposed by him to be the metatarsal bones of the Iguanadon. The longitudinal circumference of the Scarborough specimens is 11½ inches, and the transverse 10½ inches. The same mass contains also three bones, which resemble the humerus of an unknown Saurian, given in Pl. 14, fig. 3 and 6, of the same work. Their length is 14 inches ; the circumference about the middle of the shaft, 8½ inches ; and around the condyle, 16 inches. There are two other bones which are supposed to be tibias. They are ten inches long ; and their circumference at the superior extremity is 15½ inches. The circumference at the vertebral extremity of the fragment of a rib is 5½ inches, and about the middle of the bone 6 inches.

The same mass encloses also a singular bone, something resembling in form the humerus of an Ichthyosaurus : the length of the supposed, cubital, articulating extremity is 8½ inches, and the diameter 7 ; while the diameter of the cylindric part, at four inches from the above extremity, is 3½ inches. The

entire length of the bone when perfect is uncertain, but it appears to have been of gigantic size.

The only portion of a vertebra is a fragment $4\frac{1}{2}$ inches long by $2\frac{1}{2}$ inches in diameter.

It is very possible that these remains may belong to the Megalosaurus; and if this should prove to be the case, we shall have in the superior beds of the great oolite of Yorkshire, some of the interesting fossils of the Stonesfield slate

(*e.*) The seam of clay, above the ironstone, contains *Amphidesma decurtatum* with fragments of *Avicula Braamburiensis*, and of a *Gervilia*.

(*f.*) The next bed, consists of nodular ironstones, separated by alternating seams of argillaceous oolite, each layer being generally about eight inches thick. In the lower argillaceous seams at Cloughton Wyke, *Perna quadrata* occurs rather abundantly, and in the upper are the following fossils:

Melania Heddingtonensis.	Gervillia acuta.
Terebratula spinosa.	Trigonia costata.
Gryphea nani.	——— clavellata.
Ostrea Marshii.	Astarte minima.
Pecten lens.	Corbula depressa.
Plagiostoma interstinctum.	Pinna cuneata.
Avicula Braamburiensis.	Pentacrinus vulgaris.
——— echinata?	Cidaris vagans.

The most abundant of these are *Avicula Braamburiensis*, with the species resembling *A. echinata*, *Plagiostoma interstinctum*, *Gervillia acuta*, and *Astarte minima*. Of *Trigonia clavellata*, I have found a single specimen, at the junction of one of the lower argillaceous seams, with a layer of ironstone. It agrees with the fossil found in the Cornbrash. The *Cidaris vagans* is rare, and not being larger than a shilling, can have no connexion with the long tubercular spines before mentioned; but the smaller spines which I shall have occasion to mention, may belong to it.

In the hard beds of ironstone, *Ammonites Blagdeni* sometimes occurs, but more rarely than in the bed *d*.

I will now describe the upper part of the Bath oolite, at two other localities on the same range, and not more than three miles from White Nab. These points are at the northern and southern extremities of Cayton Bay, and at low water, on the south side of Carnelian Bay. At the south point of Cayton Bay we find the following descending section.

a. Soft beds of argillaceous oolite, containing *Amphidesma decurtatum*, *Belemnites compressus*, *Avicula Braamburiensis*, and large tuberculated spines of a Cidaris resembling those in the layer (*a.*) p. 231	3 feet.
b. Alternations of sandstones and carbonaceous shales	9 ——

c. Sandstone, sometimes containing *Pecopteris Williamsonis* and *Otopteris obtusa*	1 foot.
d. Tenacious blue shale; the lower part carbonaceous: in this seam all the beautiful Gristhorpe plants occur	4 feet.
e. Impure coal	3 inches.
f. Alternating sandstones, ironstones, and shales	25 feet.
g. Irony nodules	1 foot.
h. Hard granular bed, very much ironshot, especially at the fissures	8 feet.

From the occurrence of the large tubercular spines of a *Cidaris*, of *Avicula Braamburiensis*, and *Belemnites compressus* in the thin calcareous seam, (a) it appears clear to me that the upper beds of the Bath oolite, which at Cloughton Wyke and White Nab are at least thirteen or fourteen feet thick (p. 231 from the top of *a* to *f*), are here diminished to three. If this opinion be correct, all the mass of sandstones at this point, considered by Professor Phillips as belonging to his Upper sandstone and shale, must necessarily be removed from that series, and be considered as merely a local and subordinate division of the portion of the oolites of Bath and Brandsby, to which the name of Great or Bath oolite is more particularly applied; and the beds (g) and (h) will form the lower portions of the series thus removed. I should arrive at this conclusion for several reasons. 1st. The occurrence of the three fossils above alluded to, which are not met with in the cornbrash of the Yorkshire coast, the only other formation to which the calcareous bed (a) can be referred, *are found together* in the upper beds of the Bath oolite; 2ndly, the existence of beds of sandstone filled with carbonaceous fragments, evidently belonging to the upper sandstone and shale, resting upon the calcareous deposit, whilst in the immediate neighbourhood, we find the cornbrash, surmounted by the Kelloways Rock; and lastly from the absence of the blue clay, upon which the cornbrash of the vicinity reposes.

These inclosed sandstones do not appear to extend more than two miles along the coast; and I suppose they thin out beneath the low water mark in some part of Carnelian Bay, as at its northern extremity, or White Nab, we find the superior oolitic beds in their true position; whilst at its southern point, or Ewe Nab, the ferruginous beds occur as at Gristhorpe. So small a portion of the superincumbent sandstones are here exposed, owing to the low cliffs being partially covered with diluvial clay, and the beach with sand and gravel, that we cannot compare them with the section at the opposite side of the bay. On the south side of this point is a small dislocation, but from the limited space between this ferruginous bed, and the spot where the cornbrash first appears to the south, I should say that even here the sandstones are far less extensive than at Gristhorpe. In the middle of Gristhorpe Bay a singular depression of the superior rocks, sinks these measures far beneath the line of low water,

but they rise into the cliff at the southern point, where we find most of the plants figured by Prof. Phillips in his Geology of Yorkshire, and by Lindley and Hutton in their Fossil Flora of Great Britain, as from the "Upper Sandstone and Shale." How far the series continues under the sea to the southward, I have no means of ascertaining. This interesting deposit bears every appearance of a local accumulation, resulting from some eddy or current produced by the flow of a river into an estuary.

The hard granular bed (h) is literally one mass of fragments of *Millepora straminea*, large papilla of a Cidaris, resembling *C. florigemma*, an innumerable quantity of small smooth spines of another species, which I before alluded to as probably connected with *C. vagans*, a small muricated spine belonging to the same genus, and small columnar joints of *Pentacrinus vulgaris*. All these are deposited in extremely regular and even layers, which are so close to each other as completely to fill the rock; the Millepora being found only at the top. This bed, from the quantity of iron contained in it, is extremely hard, and altogether different from any other part of the series.

If the view I have taken of the sandstones, &c. be correct, it will leave but a very small number of fossils to the true upper sandstone and shale. The plants found in the seam (a) are nearly all new to geologists: the following is a list of such as have already been figured by M. Brongniart, Professor Phillips, and Messrs. Lindley and Hutton.

Pecopteris lobifolia.
——— insignis.
——— undans.
——— polypodioïdes.
——— propinqua.
——— Williamsonis.
——— acutifolia.
——— obtusifolia.
——— dentata.
——— exilis.
——— cæspitosa.
Neuropteris recentior.
——— ligata.
——— arguta.
Sphenopteris stipata.
——— Williamsonis.
Cyclopteris Beanii.
Cyclopteris digitata.
Glossopteris Phillipsii.
Tæniopteris vittata.
——— major.
Solenites Murrayana.
Lycopodites Williamsonis.
Sphæreda paradoxa.
Pterophyllum comptum.
——— pecten.
——— minus.
Otopteris cuneata.
——— Beanii.
Ctenis falcata.
Cycadites tenuicaulis.
Dictyophyllum rugosum.
Equisetum laterale.
Winged seed.

I have also in my collection several new species, especially of *Sphenopteris*, (two species,) *Glossopteris* and *Cyclopteris*.

With but few exceptions, these plants are all characteristic of the shales in which they are found. The following species also occur in the lower sandstone and shale.

Pecopteris Williamsonis.	Tæniopteris vittata.
Neuropteris ligata.	Solenites Murrayana.
Sphenopteris stipata.	Lycopodites Williamsonis.

In the same seam I have found *Cypris concentrica, Unio distortus,* (Bean) and another undescribed species of Unio. This fact, combined with the absence of marine remains, would seem to indicate that the origin of these sandstones and shales is lacustrine, a fact of which I have little doubt. If this be correct, it would appear that a considerable time must have elapsed between the deposition of the marine fossiliferous divisions forming the top of the Bath oolite and the hard ironshot seam of Crinoideæ, upon which the sandstones and shales rest.

The fossils characteristic of the oolitic seams of the great oolite are few, as they bear a general resemblance to those of the cornbrash and inferior oolite.

The long tuberculated spines of a Cidaris have not been met with in this neighbourhood in any other rock. Professor Phillips has pointed out *Pholadomya acuticostata* and *Rostellaria composita* as characteristic of the stratum, and on the coast, at least, I am not aware of the following fossils having been found in any other.

Ammonites Blagdeni.	Terebratula spinosa.
Belemnites Aalensis.	Large spines of a Cidaris.
Phasianella cincta.	

To these may be added the mass of gigantic saurian bones from the layer of ironstone.

The Bath oolite on the Yorkshire coast is not extensively used as a building-stone, but the lower part of it, and the hard crinoidal bed at Gristhorpe Bay and Ewe Nab, have been very successfully employed in erecting the piers at Scarborough. These beds are remarkably durable, and are consequently well calculated for strong water-works, where no particular smoothness is requisite. The attempt has been made to procure lime from some of the beds, but with so little success as to check further trials, especially in a country where a superior material is abundant.

General Stratigraphical Table of the Formations described in the preceding pages, but in descending order.

GREAT OR BATH OOLITE.

Cloughton Wyke and White Nab, 30 feet.

Layers of nodular ironstone and argillaceous oolite	3 feet.
Clay	1
Nodular ironstone, 6 inches to	1
Hard, blue clay, often much tinged with iron	2
Hard, blue, fine-grained oolite, sometimes ironshot	6
A hard, blue limestone	14 to 20

Cayton Bay, South Point, 51 feet.

Soft beds of argillaceous oolite	3 feet.
Sandstone and carbonaceous shales	9
Sandstone	1
Tenacious blue shale; lower part carbonaceous: Gristhorpe plants	4
Impure coal	3 inch.
Alternating sandsts., ironsts., & shales	25 feet.
Irony nodules	1
Hard granular bed, very much ironshot, especially at the fissures	8

LOWER CARBONIFEROUS SERIES.—*Cloughton Wyke and Blue Wick*, 280 feet.

A group of sandstones and shales, divided as follows:—

Laminated sandstone, containing numerous remains of beautiful ferns and cycadean plants	6 feet.	
Hard, grey sandstone	6	
Dark, shaly sandstone	8	
	—	20 feet.
Sandstones and shales of varying thicknesses. The sandstones are hard, fissile, and used as flags; total thickness about		170
Black shale		3
Soft yellow sandstone, containing stems of *Equisetum columnare* in a vertical position, with their roots downwards		8
Gritty sandstone		20
Shale		10
Hard, pale, gritty sandstone		20
Ironstone, containing a large species of Calamites, fonds of *Zamia gigas*, &c.		20
Black carbonaceous shale, no vegetable impressions; about		10

INFERIOR OOLITE.—*Blue Wick*, 83 feet.

Hard ironstone	8
Hard ironstone	4
Irregular beds of yellow sandstone, in some parts ironshot	30
Hard ironshot sandstone	1½
Irregular beds of yellow sandstone	20
Thick beds of dark grey finely grained sandstone	20

LIAS. *Upper Lias* or *Alum Shale*, 175 to 180 feet.

Shale, soft and rubbly, breaking into very small fragments, average thickness about	130
Hard tenacious shale; the laminæ break into large fragments	30
Soft shale	15 to 20

Marlstone, between Staithes and Saltburn, 130 feet.

Sandy shales, divided by bands of argillaceous irony nodules, 6 inches thick	30
Sandstone and shale	100

Lower Lias, Peakhill.

In the upper beds the marl is shaly, in the lower, compact, arenaceous, and generally of a dull blue colour, visible thickness	300

Systematic List of Fossils noticed in Mr. Williamson's *Memoir**.

GENUS AND SPECIES.	REFERENCE.	FORMATION.
Thuytes expansus	{Sternberg†, Phill. 10, fig. 11.‡, Lind. and Hut. 167§ .....}	Low. sands. and coal.
Cycadites tenuicaulis	Phill. Pl. 7, fig. 19	Great oolite.
Zamia lanceolata	Lindley and Hutton, 194	Low. sands. and coal.
Pterophyllum minus	Ad. Brongn.‖, Lind. & Hut., 67, fig. 1	L. S. & C. Great oolite.
——— pectinoïdes	Ad. Brongn.....	Low. sands. and coal.
——— comptum	Lindley and Hutton, 66	Great oolite.
——— pecten	Lindley and Hutton, 102	———
Equisetum laterale	Phill. 10, fig. 13	L. S. & C. Great oolite.
Sphenopteris? hymenophylloides	Ad. Brongn.	Low. sands. and coal.
———? longifolia	Phill. 7, fig. 17	———
——— stipata	Phill. 10, fig. 8.....	L. S. & C. Great oolite.
——— Williamsonis	Ad. Brongn., Lind. and Hut., 131 ..	Great oolite.
Cyclopteris digitata	Ad. Brongn., Lindley and Hutton, 64	L. S. & C. Great oolite.
——— Beanii	Lindley and Hutton, 44	Great oolite.
Glossopteris Phillipsii	Ad. Brongn., Lindley and Hutton, 63	———
Tæniopteris vittata.....	Ad. Brongn., Lind. and Hut., 62, 176, B	L. S. & C. Great oolite.
——— major	Lindley and Hutton, 92	Great oolite.
Pecopteris curtata	Phill. 8, fig. 12	Low. sands. and coal.
——— acutifolia	Murray, Lindley and Hutton, 157 ..	Great oolite.
——— cæspitosa	Phill. 8, fig. 10.....	———
——— dentata	Williamson, Lindley and Hutton, 169	———
——— exilis	Phill. 8, fig. 16.....	———
——— insignis	Lindley and Hutton, 106.....	———
——— lobifolia	Lindley and Hutton, 179.....	———
——— obtusifolia	Murray, Lindley and Hutton, 158 ..	———
——— polypodioïdes	Ad. Brongn., Lindley and Hutton, 160	L. S. & C. Great oolite.
——— propinqua	Lindley and Hutton, 119.....	Great oolite.
——— undans	Lindley and Hutton, 120.....	L. S. & C. Great oolite.
——— Whitbiensis	Ad. Brongn., Lindley & Hutton, 134	Low. sands. and coal.
——— Williamsonis	Ad. Brongn., Lindley & Hutton, 126	L. S. & C. Great oolite.
Lycopodites falcatus	Young and Bird¶, Lind. and Hut., 61	Low. sands. and coal.
——— Williamsonis	Ad. Brongn., Lindley and Hutton, 93	L. S. & C. Great oolite.
Neuropteris ligata	Lindley and Hutton, 69	———
——— arguta	Lindley and Hutton, 105.....	Great oolite.
——— recentior	Lindley and Hutton, 68	———

* Where more than one reference is given, the first applies to the author who named the fossil.

† Flora der Vorwelt, 1820–1826.

‡ Geology of Yorkshire, Part I., 1829. § Fossil Flora of Great Britain, 1831–1837.

‖ Prodrome d'une Hist. des Végét. Foss., 1828; and Hist. des Végét. Foss.

¶ Geological Survey, Yorkshire Coast, 1828.

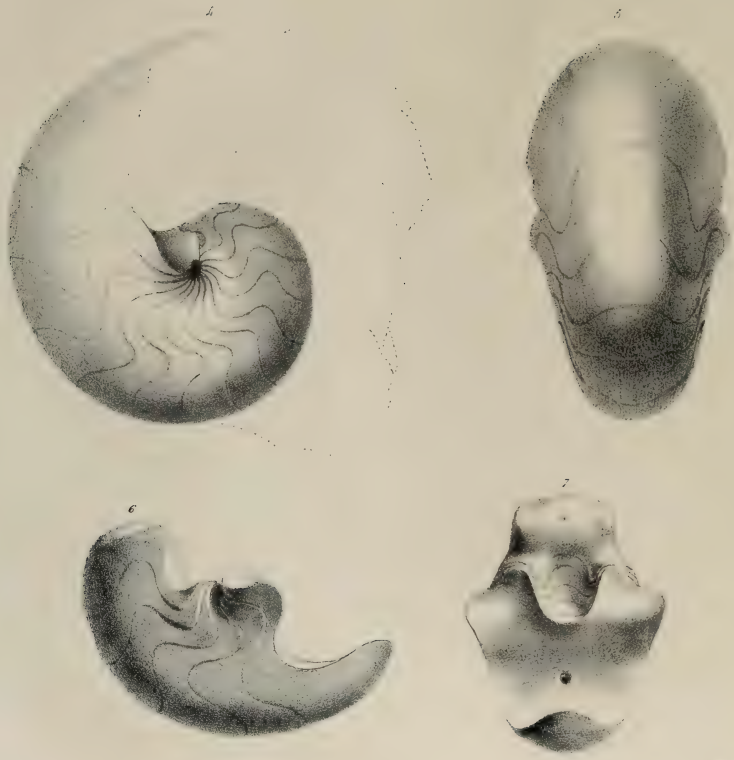
GENUS AND SPECIES.	REFERENCE.	FORMATION.
Otopteris acuminata	Lindley and Hutton, 132	Low. sands. and coal.
——— Beanii	Lindley and Hutton	Great oolite.
——— cuneata	Lindley and Hutton, 155.....	———
Tympanophora racemosa	Lindley and Hutton, 170, B	Low. sands. and coal.
——— simplex	Lindley and Hutton, 170, A	———
Solenites Murrayana	Lindley and Hutton, 121.....	L. S. & C. Great oolite.
Ctenis falcata	Lindley and Hutton, 103	Great oolite.
Sphæreda paradoxa	Lindley and Hutton, 159	———
Dictyophyllum rugosum.	Lindley and Hutton, 104	———
Polyparia.		
Caryophyllia convexa	Phill. 11, fig. 1	Inferior oolite.
Millepora straminea	Phill. 9, fig. 1	Great oolite.
Radiaria.		
Pentacrinites Briareus	Miller, Crinoidea, p. 56	Lower lias.
——— vulgaris	Schlotheim, Petref. p. 327	Low. lias. Great oolite.
Asterias Murchisoni	.....	Marlstone.
Ophiura loricata.....	Nobis	———
——— Milleri	Phill. 13, fig. 20	———
Cidaris, sp. not named	.....	———
——— large tuberculated spines	.....	Great oolite.
——— vagans	Phill. 7, fig. 1	———
——— florigemma?	Phill. 3, fig. 12	———
Crustacea.		
Astacus, species not named ..	.....	Alum shale.
——— ..	.....	Inferior oolite.
——— rostratus	Phill. 4, fig. 20	———
Cypris concentrica	Bean. MS.	Great oolite.
Conchifera.		
Gastrochæna tortuosa	Sow. 526, fig. 1*	Inferior oolite.
Pholadomya ambigua.....	Sow. 227, Vol. vi. p. 86	Lower lias.
——— Murchisoni	Sow. 545	———
——— ovalis	Sow. 226, Vol. vi. p. 86	Inferior oolite.
——— acuticostata	Sow. 546, fig. 1, 2	Great oolite.
Mya V. scripta	Sow. 224, fig. 2—5.....	Marlstone.
—— litterata	Sow. 224, fig. 1	Marlstone. Inf. oolite.
—— calceiformis	Phill. 11, fig. 3	Great oolite.
Corbula cardioides	Phill. 14, fig. 12	Marlstone.
——— depressa	Phill. 9, fig. 16.....	Great oolite.
Amphidesma recurvum	Phill. 5, fig. 25.....	Marlstone.
——— decurtatum	Phill. 7, fig. 11.....	Great oolite.
Astarte elegans	Sow. 137, fig. 3	Inferior oolite.

* Mineral Conchology of Great Britain, 1812—1829.

GENUS AND SPECIES.	REFERENCE.	FORMATION.
Astarte minima	Phill. 9, fig. 23	Inf. and Great oolite.
Cardium truncatum	Sow. 553, fig. 3	Marlstone.
——— multicostatum	Phill. 13, fig. 21	———
——— incertum	Phill. 11, fig. 5	Inferior oolite.
Cardita similis	Sow. 232, fig. 3	Inf. and Great oolite.
Isocardia lineata		Marlstone.
——— concentrica	Sow. 491, fig. 1	Inferior oolite.
Cucullæa cancellata	Phill. 11, fig. 44	Great oolite.
Nucula ovum	Sow. 476, fig. 1	Alum shale.
——— axiniformis	Phill. 11, fig. 13	———
Trigonia literata	Phill. 14, fig. 11	———
——— angulata	Sow. 508, fig. 1	Inferior oolite.
——— costata	Parkinson, Org. Rem. III. 12, fig. 4	Inf. and Great oolite.
——— gibbosa	Sow. 235, 236	Inferior oolite.
——— striata	Miller, 237, fig. 1—3	———
——— clavellata	Parkinson, Org. Rem. III. 12, fig. 3	Great oolite.
——— duplicata	Sow. 237, fig. 4, 5	———
Unio abductus	Phill. 11, fig. 42	Inferior oolite.
—— distortus	Bean	Great oolite.
Hippopodium ponderosum	Sow. 250	Lower lias.
Modiola scalprum	Sow. 248, fig. 2	Marlstone.
——— Hillana	Sow. 212, fig. 2	———
——— cuneata	Sow. 211, fig. 1	Inferior oolite.
——— pulchra	Phill. 5, fig. 26	———
Mytilus sublævis	Sow. 439, fig. 3	———
Pinna folium	Y. & B. 10, fig. 7. Phill. 14, fig. 17	Lower lias.
——— cuneata	Phill. 9, fig. 17	Great oolite.
Perna quadrata	Sow. 492	———
Gervillia acuta	Sow. 510, fig. 5	———
Inoceramus dubius	Sow. 584, fig. 3	Alum shale.
Avicula cygnipes	Y. & B. 9, fig. 3. Phill. 14, fig. 3	Marlstone.
——— inæquivalvis	Sow. 244, figs. 2, 3	Marlst. Alum shale.
——— echinata?	Sow. 243, fig. 1	Inferior oolite.
——— Braamburiensis	Sow., Phill. 6, fig. 6	Inf. and Great oolite.
Plagiostoma læviusculum	Sow. 382	Marlstone.
——— interstinctum	Phill. 7, fig. 14	Great oolite.
Pecten æquivalvis	Sow. 136, fig. 1	Marlstone.
——— sublævis	Phill. 14, fig. 5	———
——— abjectus	Phill. 9, fig. 37	Inferior oolite.
——— virguliferus	Phill. 11, fig. 20	———
——— lens	Sow. 205, figs. 2, 3	Great oolite.
Plicatula spinosa	Sow. 245	Lower lias. Marlstone.
Gryphæa depressa	Phill. 14, fig. 7	Lower lias.

GENUS AND SPECIES.	REFERENCE.	FORMATION.
Gryphæa incurva	Sow. Y. & B. 8, fig. 13.....	Lower lias.
———— Macullochi.....	Sow. 547, figs. 1–3	————
———— bullata	Sow. 368	Marlstone.
———— nana	Sow. 383, fig. 3	Great oolite.
Ostrea, species not determined.	.....	Marlstone.
——— Marshii	Sow. 48	Inf. and Great oolite.
——— solitaria.....	Sow. 468, fig. 1	Inferior oolite.
Orbicula reflexa.....	Sow. 506, fig. 1	Alum shale. Inf. oolite.
Terebratula bidens.....	Phill. 13, fig. 24.....	Marlstone. Inf. oolite.
———— tetrahedra	Y. & B. 8, fig. 15.	Marlstone.
———— triplicata	Phill. 13, fig. 22.....	————
———— obsoleta	Sow. 83, fig. 7	Inferior oolite.
———— trilineata	Young and Bird	————
———— spinosa	Smith, Phill. 9, fig. 18	Great oolite.
Lingula Beanii	Phill. 11, fig. 24.....	Inferior oolite.
Mollusca.		
Auricula Sedgvici	Phill. 11, fig. 33.....	Inferior oolite.
Melania Heddingtonensis	Sow. 39. Y. & B. 11, fig. 18	Inf. and Great oolite.
Nerita costata.....	Sow. 463, figs. 5, 6	Inferior oolite.
Natica adducta	Phill. 11, fig. 35.....	————
——— tumidula	Phill. 11, fig. 25.....	————
Actæon humeralis	Phill. 11, fig. 34.....	————
——— glaber	Phill. 9, fig. 31	————
Vermetus compressus	Phill. 4, fig. 17	————
Dentalium giganteum.....	Phill. 14, fig. 8	Marlstone.
Trochus depressus.....	Nobis	Alum shale.
———- bisertus.....	Phill. 11, fig. 27.....	Inferior oolite.
———- arenosus	Sow. 220, fig. 2. Cor. vol. 4.....	————
———- pyramidatus.....	Phill. 11, fig. 22.....	————
———-, species not named ..	.....	Great oolite.
Turbo undulatus.....	Phill. 13, fig. 18.....	Marlstone.
——— funiculatus	Phill. 4, fig. 11	Inferior oolite.
——— lævigatus.....	Phill. 11, fig. 31.....	————
Phasianella cincta	Phill. 9, fig. 29	Great oolite.
Turritella cingenda.....	Sow. 499, fig. 3	Inferior oolite.
-———— humifusa	.....	————
———— muricata	Sow. 499, fig. 1 and 2.....	————
———— quadrivittata	Phill. 11, fig. 23.....	————
Rostellaria composita.....	Sow. 558, fig. 2	Inf. and Great oolite.
Terebra vetusta	Phill. 9, fig. 27	————
Belemnites compressus	Voltz (not De Blainville)	L. lias. Marls. Al. shale
———— elongatus	Geol. Tr. 2nd ser., ii. 7, fig. 6	Marlstone.
———— tubularis	Y. & B. 15, fig. 6. Phill. 12, fig. 20	Alum shale.
————-, species not named.	.....	Inferior oolite.

GENUS AND SPECIES.	REFERENCE.	FORMATION.
Belemnites Aalensis	Voltz	Great oolite.
——— compressus	De Blainville, Sow. 590	———
Nautilus astacoides.....	Y. & B. 13, fig. 2. Phill. 12, fig. 16	Alum shale.
Ammonites cornucopia	Y. & B. 12, fig. 8. A. fimbriatus, Sow. 164	Lower lias.
——— planicostus	Sow. 73	———
——— Clevelandicus	Y. & B. 13, fig. 7. Phill. 14, fig. 6..	Marlstone.
——— Stokesii	Sow. 191	———
——— Hawkerensis	Y. & B. 14, fig. 6. Phill. 13, fig. 8..	Marlstone. Alum shale.
——— annulatus.....	Sow. 222, fig. 2	Alum shale.
——— communis	Sow. 107, fig. 2. Y. & B. 12, fig. 3.	———
——— crassus.....	Young and Bird, p. 253.....	———
——— elegans.....	Sow. 94, upper fig.	———
——— exaratus	Y. & B. p. 266. Phill. 13, fig. 7....	———
——— fibulatus	Sow. 407, fig. 2	———
——— heterophyllus	Sow. 266	———
——— ovatus	Y. & B. 13, fig. 4. Phill. 13, fig. 10	———
——— Walcotii	Sow. 106	———
——— concavus	Sow. 94. lower fig.	Inferior oolite.
——— inornatus.....	Nobis, MS.	———
——— striatulus.....	Sow. 421, fig. 1	———
——— Blagdeni	Sow. 201	Great oolite.
Pisces	.....	Alum shale.
Reptilia.		
Ichthyosaurus communis	Conyb., Geol. Trans., 1st series, vol. v., & De la Beche, 2nd series, vol. i.	Alum shale.
? ——— tenuirostris		
Megalosaurus?	.....	Great oolite.
Plesiosaurus	.....	Alum shale. G. oolite?
Teleosaurus Chapmanni.....	Young and Bird, Pl. XVI. fig. 1	Alum shale.



1 2 3 Cypræa bullaria 4 5 6 7 Nautilus Danicus

XX.—*On the Cretaceous and Tertiary Strata of the Danish Islands of Seeland and Möen.*

By CHARLES LYELL, Esq., P.G.S., F.R.S., &c.

[Read May 13, 1835.]

A PAPER was published by Dr. Forchhammer, of Copenhagen, in the 17th number of the Edinburgh Journal of Science, July, 1828, in which he seemed to have established the fact of a passage from the chalk into certain tertiary strata, and to have proved it, not only by the occurrence of certain species of fossil shells common to the one series and to the other, but also by the alternation of strata, each exhibiting the mineralogical characters respectively belonging to the chalk and the more recent deposits.

The above-mentioned conclusions were drawn from observations made nearly fifteen years ago, at a period when little was known of the geology of Denmark, especially of the organic remains of that country; it is right therefore to state at once, that Dr. Forchhammer has since changed his views on the principal points which I am about to discuss.

The following was the series of superimposed formations originally imagined by Dr. Forchhammer to occur in Denmark: first, beginning with the oldest group in Seeland, white chalk with flints in the cliffs of Stevensklint, with the usual chalk fossils; next above a seam of bituminous clay and other strata, consisting of yellow limestone, in which occurred fossils of genera "usually considered characteristic of tertiary rocks". Thirdly, above these, in the same cliff, a coralline limestone approaching more nearly to white chalk in its fossils and mineral composition. It was then supposed that the white chalk with flints occurring in Möen, and containing the ordinary chalk fossils, was still newer than the limestone last mentioned, and yet this same Möen chalk was said to alternate, and to have been deposited contemporaneously, with masses of clay and sand containing boulders*.

It was impossible to read this statement without being convinced, that the cretaceous rocks of Denmark must present some very singular and anomalous appearances: I was therefore desirous in 1834 of visiting Seeland and Möen,

* Edinburgh Journal of Science, No. 17, p. 67. 1828.

in company with Dr. Forchhammer, and was fortunate enough to find him disengaged in the spring of that year, and willing to conduct me to the sections which he had described.

Baltic Boulder Formation.

That part of Denmark which we passed over between Copenhagen and Möen consists of what many geologists would term "diluvium," but for which Dr. Forchhammer proposes the name of the "Baltic boulder formation," because it incloses, together with boulders of granite and other rocks, huge erratic blocks, evidently transported from a distance, and which may be called "Baltic," because they are chiefly confined to countries bordering that inland sea, as for example, to Sweden, Finland, Northern Germany, and Denmark.

This "drift," or "boulder formation," rests in some places immediately on the chalk, as in the districts of Seeland and Möen, of which I am more particularly to speak in this notice; but in many parts of Denmark, other tertiary strata are interposed between it and the chalk. In these cases, the boulder formation and other tertiary deposits exactly recall the "diluvium" and crag strata in the cliffs of Norfolk and Suffolk. The identity, indeed, in the appearance and composition of the masses which cover the fossiliferous crag in parts of Norfolk and Suffolk, with those seen in Holstein and other parts of Denmark, is so perfect that it can only be fully appreciated by those who have seen both. The accumulations of stratified and unstratified materials are in both countries the counterparts of each other.

No natural sections of considerable depth, are seen in these formations in the interior of Denmark, but they may be studied with advantage in the cliffs forming the right bank of the Elbe, below Hamburgh. A few words respecting the cliffs there will be useful, as I am not aware that they have been yet described.

A nearly continuous section is seen from the point of Blankenese, west of Altona, to the village of Schulau, a distance of about three miles. Throughout this space, the precipitous cliffs are from fifty to eighty feet in height, and are undermined at certain points by the river. Their composition is extremely various. At their western extremity, near Schulau, they are principally composed of a great succession of thin layers of yellow and white quartzose sand, with loam, and a few beds of flinty gravel. These sandy strata extend from the base of the cliffs to their summit, as also to the top of the hills immediately behind, so that they must be upwards of 200 feet in thickness above the sea level, and perhaps much more below it, no older rocks appearing in the neighbourhood. The beds of sand at Schulau have frequently a diagonal lamination.

The only shells which I was able to procure, after a careful search, were found on the face of the cliffs at Schulau, and consisted of an imperfect univalve, and one valve of a Venericardia, not of a recent species, as Dr. Beck ascertained, after comparing it with the shells in the valuable collection

of H. R. H. Prince Christian, at Copenhagen. (See fig. 1.) It is probably *Venericardia senilis* of the crag (Sowerby Min. Con. tab. 258. figs. 1. 2. 3.), a shell which varies greatly in form, but of which I have seen some specimens from Suffolk, which are equally transverse.

Fig. 1.

Left valve of a Venericardia, from Schulau, Holstein.

I was informed that, at some places in the interior of Holstein, beds of marl, used in agriculture, abound in this formation, containing about twenty per cent., and often more, of carbonate of lime. In several places between Schulau and Blankenese the stratified sand and loam gives place suddenly to the boulder formation, consisting of stiff blue and greenish clay, often entirely destitute of stratification, and having interspersed irregularly through it, pebbles and blocks of granite, gneiss, hornblende-schist, white chalk-rubble, rounded and angular masses of chalk, entire and broken chalk flints, black rounded pebbles of flint, and a variety of other rocks.

Although I believe the largest boulders occur chiefly in the upper part of this deposit, yet I saw in the perpendicular cliff, near Blankenese, some huge blocks of granite distinctly imbedded at a considerable depth. Professor Schumacher, of Altona, informed me that he had selected two erratic blocks of granite, lying on the surface of this country, to serve as well-marked points for the extremities of the base which he measured for his trigonometrical survey. One of these blocks was about six feet square, and the other about eight feet long, by five in breadth and depth. But others have been observed in Denmark of much larger dimensions, measuring no less than twenty feet in diameter in two directions.

I infer from the sections on the Elbe, that the stratified sand and loam were originally continuous throughout the space where the cliffs now extend, and that the sudden and abrupt manner in which the unstratified drift, containing boulders, now occasionally replaces the sands, is owing to subsequent changes. Such a relative position may perhaps be due to the engulphment, during earthquakes, of superincumbent mud and boulders; for I could not, when on the spot, reconcile the phænomena with the idea of valleys excavated in the more ancient sands, and subsequently filled up with the boulder formation. Under any hypothesis, it is difficult to conceive how such enormous heaps of gravel, sand, clay, and boulders, have been collected together without any arrangement, such as would be produced by the sorting power of running-water acting on materials which differ in size, shape, and specific gravity. Had the deposit been only a few feet thick, and all the boulders of moderate dimensions, it might have been argued, that a violent current of water, or diluvial wave, had thrown together materials of all sizes in one promiscuous mass, and left them as devoid of arrangement as a quantity of rubbish shot from a cart. For my own part, I am unable to suggest any conjecture to account for the phænomena, except that of islands of drift ice, loaded with earth, gravel, and blocks, or having these substances frozen into them, and then melting. In this case, all the materials transported from a distance, might

fall down from still water in the most complete disorder. It must not be supposed, however, that all the masses containing boulders and erratic blocks in Denmark and Sweden, are void of stratification. This is far from being universally true, and in both these countries, they contain, here and there, marine shells of recent species. It has also been stated that fossils of extinct species, and of the older tertiary periods, are sometimes met with in similar deposits; but of this fact, I have never yet obtained decisive proof. Nor was I able to procure sufficient data for determining the age of the yellow sand and loam before mentioned, which contains the Venericardia, near Schulau.

White Chalk and Coralline Limestone of Stevensklint.

Having offered these few observations on the newer deposits, I shall next consider the cretaceous rocks which are exposed to view on the eastern coasts of Seeland and Möen.

On proceeding south from Copenhagen, I first saw the solid rocks make their appearance from underneath the overlying loam and gravel at Stevensklint, or "the Cliffs of Stephen," well known in the Baltic by the lighthouse which crowns them. These cliffs extend for five or six English miles along the shore, with a mean height of about sixty or seventy feet, and are, with few exceptions, perpendicular, and continually wasting away. The lowermost beds are nearly horizontal, but have a slight dip to the south-west. They consist of soft white chalk, with parallel layers of flint, and the fossils which have been collected from them agree specifically with those of the upper chalk in England and France. I did not examine the loftiest part of this line of cliff, but Dr. Forchhammer estimates the thickness of white chalk, seen above the level of the sea, to amount to about eighty feet. Beds of nodular flint occur parallel to the stratification, and one thick bed of flint is very conspicuous, and may be traced for a great distance, in a nearly horizontal line.

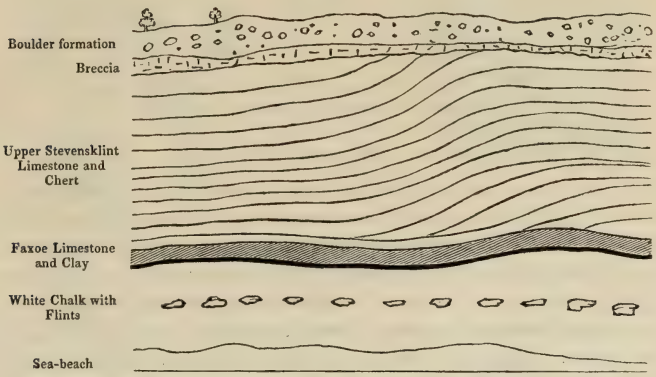
Immediately upon the surface of the white chalk, at Stevensklint, is a layer of bituminous laminated clay, from one to several inches in thickness, which marks strongly the beginning of a new set of strata, and to which we have nothing analogous in our upper cretaceous system in England. Above the clay is a yellowish limestone, harder than white chalk, which I shall call the Faxoe limestone, because it is more fully developed at Faxoe*, a locality about ten miles distant. Like the clay, it contains some peculiar fossils, especially many univalve shells, together with other organic remains usually found in chalk. At Stevensklint, the Faxoe limestone varies in thickness from one to three feet, and passes upwards into a white chalky rock, including a great number of broken corals, together with bivalve and other shells common to the white chalk.

This superincumbent mass I shall call the upper Stevensklint limestone. It is made up almost entirely of broken and pulverized zoophytes, and forms an excellent building stone, for which it is used as often as large fragments fall down upon the beach from the undermined cliff. It is divided into beds

* Misspelt Taxoe, in Brewster's Edinburgh Journal of Science, July, 1828

by continuous layers of impure flint or chert, of an opaque brown or greyish colour, and containing silicified zoophytes. A few nodules of chert occur between the continuous beds of the same. These beds are commonly not horizontal, like the flint of the chalk below, but are arranged in diagonal layers, often inclined at angles of 25° to 35° and more. (See fig. 2.) This diagonal structure has not been caused by subsequent disturbance, but appears clearly, from analogy of form, to be due to the same causes which give rise to diagonal lamination in sandy and other strata; yet in this, and many similar instances, the shape and inclination of the beds may probably have been modified in some degree during the solidification of the mass, when the flinty and calcareous matters were separating, and the zoophytes becoming silicified.

Fig. 2.

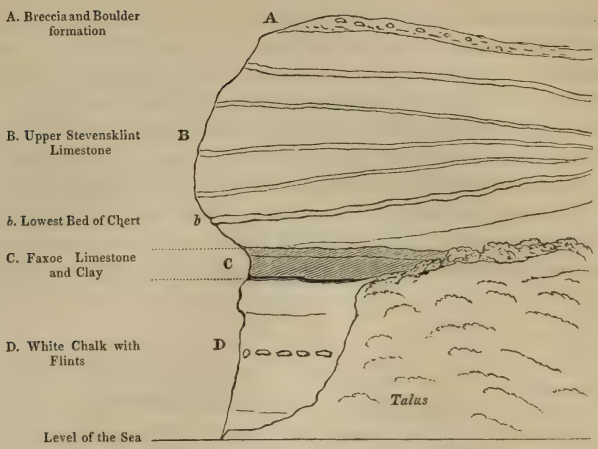


Section in the Cliff near the Church of Hoierup, Stevensklint.

The undulating lines in the annexed figure 2, represent the arrangement of the layers of chert in a small part of the cliff, but it would require a much more extended view to give an adequate idea of the manner in which these beds sometimes interfere with and cut off each other. The height from the top of the cliff in this sketch to the bed of laminated clay, is about thirty feet.

The upper Stevensklint limestone, above mentioned, forms an overhanging mass, the Faxoe bed, though harder, weathering away more rapidly, and splitting naturally into small fragments. The annexed sketch (fig. 3.) will show the outline of one of the small promontories, as seen in profile projecting from the cliff.

Fig. 3.



Cliff between Hoierup and the Lighthouse, Stevensklint.

Coral Limestone of Faxoe.

When we endeavour to trace the upper limestones above described from the sea-cliffs into the interior of the country, we find that they are entirely concealed beneath the covering of breccia and the boulder formation, but about ten miles south-west of Stevensklint, the inferior or Faxoe bed, is found in great thickness on the summit of one of the highest hills in Seeland. Its existence has also been detected at some intermediate spots by the digging of pits and wells. Large quarries which I visited with Dr. Forchhammer have been opened in these beds at Faxoe, and they supply excellent building stone, consisting of a hard yellowish limestone, the thickness of which can be traced to the depth of forty feet, without any signs of coming to an end. Sometimes corals are very abundant in this stone, so that large masses appear entirely composed of zoophytes. Two species are peculiarly abundant, *Caryophyllia Faxoensis*, Beck*, (see figure 4), and another† (see figure 5.). In some places there are patches of coral cemented together by white chalk, but with these exceptions, no portion of our oolitic rocks can less resemble ordinary

* I have to acknowledge the kindness of Dr. Beck in supplying me with a faithful drawing of this coral, which he has had made from a specimen in the collection of H. R. H. Prince Christian.

† This coral approaches to the genus Isis in having stony articulations, which are concentrically striated at each end, but it differs from Isis in the younger branches being hollow, and in other particulars.

chalk than the stone of Faxoe. Even those parts of the stone which are most compact often exhibit under the lens evident marks of coralline structure, and they are traversed by vermiform cavities*.

Fig. 4.

Caryophyllia Faxoensis, Beck.

Fig. 5.

Coral allied to Isis, from the Limestone of Faxoe.

The shells in the Faxoe limestone are in the state of casts. Dr. Beck has drawn up a list of the fossils found in the chalk of Denmark, and in the Faxoe limestone, which it is to be hoped he will soon publish, accompanied by a description and figures of the new species. In the meantime, he has liberally permitted me to consult his lists, and I shall now endeavour to point out some of the geological conclusions, which seem, to me, to be fairly deducible from the result of his examination of several hundred fossils.

The most striking circumstance respecting them as strictly belonging to the cretaceous era, is the great number of spiral univalves, which it is well known are exceedingly rare in the white chalk throughout Europe. Thus, for example, there are two species of Cypræa†, one of Oliva, two of Mitra,

* These cavities, Mr. Darwin thinks, are bored by Annelides, and they are so common in the limestone of modern reefs, that he has assigned them as a general characteristic in the structure of recent coral limestone. The same gentleman tells me, that the Faxoe stone resembles that formed in shoal water on modern reefs, and he believes that some of it may have originated at the surface.

† One of these is figured in Plate XVIII. figs. 1, 2, 3.

four of the genus Cerithium, six of Fusus, two of Trochus, one of Triton, one of Nassa, one of Bulla, and several others. There is also a Patella, and an Emarginula. On the whole, there are more than thirty univalves, spiral or patelliform, and not one of them is common to the Faxoe formation and the white chalk. Yet of the Brachiopoda found with these, no less than ten can be identified with species of the chalk, and there are an equal number of Lamellibranchiate bivalves, which are identical. A still greater proportion of sponges, corals, and other zoophytes found at Faxoe, agree with those of the chalk, no less than forty-two having been identified out of 104 procured from the two formations in Denmark. Of Crinoidea and Echinodermata, fourteen species are ascertained to be common to the two formations, also two species of Foraminifera, and two of Annelidæ.

The Cephalopoda of Faxoe deserve also particular mention, two of them, *Baculites Faujasii* and *Belemnites mucronatus*, being common to the white chalk and to Faxoe, and there being an Ammonite, as well as two species of Nautilus in the Faxoe beds, a fact which some will consider as peculiarly interesting, since so many carnivorous trachelipods are associated with these cephalopoda*.

The above statements will be sufficient to satisfy a geologist, that the Faxoe fossils belong to the cretaceous period. The univalve shells which constitute their peculiar character are not identical with any known tertiary species, and have therefore merely a generic resemblance to tertiary fossils.

It may naturally be asked, why so many univalves should be found in this rock, whereas they are almost entirely absent from the white chalk. This might be supposed to arise from one of two causes, first the local conditions of the spot where the stone of Faxoe was formed, which may have been more fitted for the existence and multiplication of univalve testacea; secondly, the stony matrix of Faxoe may have been more favourable for their preservation. Both causes may have operated, but probably the latter has been most influential, for the shells themselves have disappeared, even at Faxoe, being only recognizable by casts, which the softer chalk might not have retained. Dr. Beck has also pointed out to me a curious fact

* I have been favoured by Dr. Beck with drawings, both of *Cypræa bullaria*, and *Nautilus Danicus*, Schlotheim, pp. 117 and 83, both from Faxoe specimens in the collection of H.R.H. Prince Christian. A considerable degree of interest has been attached to *N. Danicus*, since Mr. Von Buch declared his opinion that it was specifically identical with *Nautilus aganiticus*, Mont., which Count Münster, following Sowerby, calls *N. sinuosus*. (Leonhard and Bronn's Neues Jahrbuch, 1834, p. 533.) Dr. Beck has, in our Proceedings, vol. ii. p. 218., denied this identity, and Schlotheim had previously pointed out the differences. (Petrefactenkunde, p. 83.) The annexed figures (Plate XVIII.) will enable the zoologist to form his own opinion on this subject.

which seems highly confirmatory of this view. We meet very commonly in the chalk with the solid support of the *Hipponyx*, the body of the shell being the same in form and structure as a *Pileopsis*, and this part having entirely disappeared. We also find the lower valves of *Crania* in white chalk, these valves being of the ordinary texture of bivalves, whereas the upper valves of the same, which are less solid, are rarely if ever met with. According to this analogy, the white chalk, even if it originally contained univalves as abundantly as the Faxoe limestone, might now be destitute of them, and might present us solely with bivalve shells*.

Among other remains at Faxoe, the claws and entire shells of a small crab, *Brachyurus rugosus*, Schlotheim, are not uncommon. Such crustacea abound on modern coral reefs, to which the mass of zoophytic limestone at Faxoe bears so close a resemblance.

The next point which I shall consider, is the age of the Faxoe beds, relatively to the white chalk with flints. Although we have the evidence of direct superposition at Stevensklint, that some beds of the Faxoe formation were posterior to certain beds of white chalk, yet this circumstance appears to me by no means conclusive of the general posteriority of the Faxoe corals and other shells to all the white chalk of Europe, or even of Denmark. I may observe that, although at Faxoe itself the coral limestone containing univalves is the uppermost mass, or covered only with tertiary drift and boulders, yet at Stevensklint, a rock (*b*. fig. 6.) containing similar fossils and resting on white chalk, is by no means the newest of the cretaceous series, but is again covered by a rock of considerable thickness, which I have called the upper Stevensklint limestone (*a*. fig. 6.), and the fossils of this last correspond much

Fig. 6.

a Upper Stevensklint limestone.
b Faxoe limestone.
c White chalk.

Interval of nine miles unknown.

Depth of *b* unknown.

more closely to the white chalk, and are not distinguished by the most characteristic remains of Faxoe. This fact seems clearly to show, that the distinct-

* Since writing the above, Mr. Lonsdale has shown me many specimens of the upper valves of crania, which he has found in an excellent state of preservation in the soft white upper chalk of Gravesend and Portsdown in this country. He suggests that the supposed comparative abundance of the lower valves may arise from their being attached to large fossil bodies.

ness of the fossil fauna of Faxoe, was produced more by geographical conditions, such, for example, as the local shallowness of that part of the cretaceous sea, than by any general change in the creatures inhabiting the ocean, effected in times intervening between the formation of the white chalk and the Faxoe limestone.

We know from the observations of Lieut. Nelson, in the Bermudas, that the decomposition of certain corals or calcareous zoophytes, produces chalk, or a pure calcareous mud, which only requires a slight degree of consolidation to be identical with chalk. It is on islands and shoals that such corals abound, and are continually decomposing; and the white mud thence derived, is carried out and spread over the deeper parts of the adjoining sea. If any of these deeply submerged parts should afterwards become shallow, whether by upheaval from below, or by filling up with mud, they may also support corals of the same species as those from the decomposition of which the chalky mud was first derived; while at the same time more chalk will continue to be formed in the depths of the surrounding sea*.

In this manner white chalk and coral limestone may be made to alternate, or if not, they may both be formed contemporaneously in the shallow and deep parts of the same ocean. It seems to me, therefore, that the shells and corals of Faxoe, some of which are even there imbedded in true chalk, throw great light on the state of the northern ocean during the cretaceous period, and on the nature and origin of that remarkable deposit, the white chalk.

The chalk of St. Peter's Mount, Maestricht, bears undoubtedly much resemblance, both in its mineral character and genera of fossils to that of Stevensklint; but Dr. Beck is of opinion that some of the upper cretaceous beds in Belgium approach more nearly in their species of fossils to the Faxoe limestone than the Maestricht deposit†.

Chalk and Boulder Formation of Möen.

I shall now pass on to the cliffs of the island of Möen, which are from 300

* Since Lieut. Nelson's communications were made to the Society, and since the reading of this paper, Mr. Darwin has brought home much valuable information respecting the growth of coral, both in islands and the barrier reefs skirting continents, and has found that the disintegration of the zoophytes, gives rise continually, and on a large scale, to pure calcareous mud, which, when dry, resembles chalk. The same geologist informs me, that the excrement of certain fish of the genus Sparus, and of inferior tribes of marine animals, which prey on coral, consists of impure chalk. These fish are seen in great numbers feeding quietly on living corals, just as herds of herbivorous animals graze on herbage, and on opening their bodies, Mr. Darwin found the intestines filled with similar chalk.

† See Proceedings of Geol. Soc., No. 43, p. 218.

to 500 feet high, and in many places composed of white chalk from top to bottom. The beds are partly vertical, partly curved, and have undergone extreme disturbance. As we find a range of the English chalk in Purbeck and the Isle of Wight, where the strata are much dislocated and thrown on their edges, while in the immediate neighbourhood of the line of convulsion strata of similar chalk are traced over a wide area in horizontal or slightly tilted position, so in Denmark we remark the like contrast between the state of the white chalk with flints, which occur in the neighbouring islands of Seeland and Möen.

The first view which I obtained of the Möen cliffs was from the sea, when I passed them at the distance of about a mile, in a steam boat. Although they much resemble the white cliffs of the south of England, yet I could see, even at this distance, that they were more subdivided by deep ravines into separate and distinct masses. The soil at the bottom of these ravines is dark, mostly clothed with wood, and comes quite down to the sea. They are in fact narrow clefts, coinciding with lines of fracture and dislocation; vast masses of sand, clay, and gravel, of the incumbent boulder formation, having been thrown down bodily into chasms. At the same distance, may be seen in front of, and in the lower part of most of the perpendicular chalk cliffs, an inclined plane resembling a talus, which I afterwards ascertained to consist, in many places, of a sloping mass of solid chalk *in situ*.

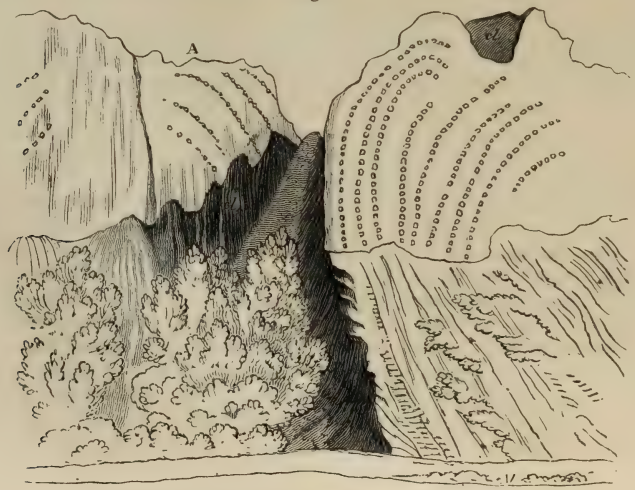
I began my examination of Möen at the northern extremity of the line of high cliffs, and found the first opening, or narrow valley, near a rock called Taleren. A deep ravine here comes down, at right angles to the line of coast. At the bottom is a small stream which has worn its way through clay and sand. The channel is so narrow and steep that I climbed up it with difficulty. On both sides are walls of chalk, from one to 300 feet in height, but the wall on the southern side, or what, with reference to the streamlet, may be called the right side, does not consist of chalk to the bottom, the fundamental mass being composed of beds, occasionally distinct, of blue clay and yellow sand, which at first conveyed to Dr. Forchhammer the notion of an alternation of deposits of chalk and clay. But when we climb to the head of the ravine, and obtain a general view of the southern wall above alluded to, we see that there must have been two fissures into which the clay and sand have been introduced, one vertical and at right angles to the coast, and the other in a direction nearly parallel to the coast, but with an oblique hade inclined towards the sea. The effect of the latter fissure has been to allow a mass of stratified sand and gravel to slide down bodily in sloping beds, dipping seaward at a high angle. Its appearance, as seen from above, is represented in the annexed sketch, where the perpendicular cliff is more than 200 feet high. The dark strata at the bottom represent clay and sand, immediately below which is the bed of the torrent. It will be seen, that the continuous beds of flint are in some places vertical, and in others curved. Clay and sand similar to that in the ravine, and containing gravel and boulders, are found on the top of the chalk, at the head of the ravine, and on the surface of the country in the interior.

Fig. 7.

Chalk with Flints resting on Clay. Taleren, Möen.

There is another great line of fracture in the chalk further to the south at Sommerspiret, where another ravine, filled with clay and sand, descends to the sea. Here, as afterwards in a third break in the cliffs further south, I observed the strata of chalk dipping on the opposite sides of the ravine towards the hollow, as seen in fig. 8.

Fig. 8.



View from the Sea-beach of the Ravine at Sommerspiret.

The dark parts represent clay and sand, the rest chalk with flints. The steep inclined plane represented in front is that before mentioned as having the appearance of a talus, but which is in fact composed of solid chalk with flints, strewed over with detritus of chalk. The height from the summit of the cliff to the sea, at Sommerspiret, was by conjecture about 300 feet. The superposition of the chalk to the clay is not so evident as at Taleren, yet a side view of part of the northern precipice gives the accompanying curious section (fig. 9.), where a great mass of sand (*s. s.*) is seen let into the chalk, and a huge fragment of chalk is again included in the midst of the sand. I know not the exact height of the precipice in this section, but it is perhaps eighty feet.

Fig. 9.

Ch. Chalk with Flints. *s. s.* Sand.

In projecting promontories of the cliffs between Taleren and Sommerspiret, masses of blue clay are seen intersected in the chalk, in the manner represented in the annexed drawing, fig. 10.

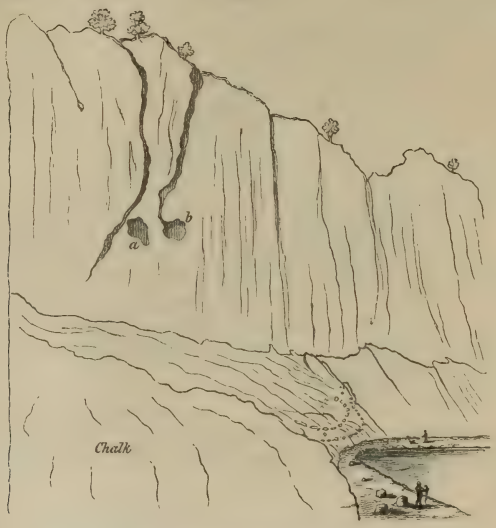
Fig. 10.

ch. Chalk with Flints. C. Blue Clay, 7 feet thick.

The cliff called Dronningestolen is between 300 and 400 feet in height, nearly three-fourths of which are perpendicular, but the lower part is a sloping mass of solid chalk with flints, the beds of flint being highly inclined towards the sea. This cliff is represented in the annexed sketch

(fig. 11.). Two rents are seen descending perpendicularly downwards from the surface of the country, and terminating the one at the depth of about 100, and the other at more than 150 feet from the top of the cliff. They are filled with sand, and near their termination are two caves, *a*, *b*, partially filled with sand, one of which is fourteen and the other sixteen feet high. These caves, which may be sections of long subterranean passages, are distinctly connected with dislocations in the chalk, some of which could not be seen from the point of view where the sketch (fig. 11.) was taken.

Fig. 11.



View of the Cliff called Dronningestolen, Island of Möen.

a. b., Caves.

Without entering further into local details, I may state, that wherever in Möen masses of sand and clay are included in the midst of the chalk, a connection may be traced between them and the upper surface of the cliff by lines of fracture in the chalk, usually filled with similar sand and clay.

A few apparent exceptions will naturally occur, in consequence of that removal of rock by which the cliffs were formed; but we may suppose that such insulated patches of clay as are represented in fig. 10 may have been prolonged upwards towards the summit of chalk, which has been carried away on the side of the sea.

I have already stated that the ravines descending to the sea coincide in position with great lines of fracture, and the various phenomena of the intercalation of clay, sand, and gravel in the chalk, and the entanglement of the

two formations may be explained by supposing the convulsions to have happened at the bottom of the sea when the chalk was already overspread by the boulder formation, which may sometimes have slid down bodily and in stratified masses into rents which opened beneath them. The superior deposits seem to have been swallowed up in the same manner as houses and villages have been suddenly engulphed by modern earthquakes, and the upper parts of some chasms may occasionally have closed in again. These movements have produced sharp curves in some places, and in others great faults in the strata of chalk, which are beautifully marked by the lines of black flint. Occasionally a mass of chalk divided by regular layers of inclined flints abuts abruptly against another, in which no flints or scarcely any are visible. Almost every other imaginable form of dislocation may sometimes be met with. I did not see any flints shattered *in situ*, and I am told that they have rarely been observed; but I cannot agree with Dr. Forchhammer in the inference which he draws from this fact, namely, that the flints were not fully separated from the calcareous matter when the convulsions happened*. I can however readily believe, that they were less brittle when beneath the sea, as they probably were more impregnated with water than now.

It is well known, that in the English cliffs near Trimmingham, in Norfolk, large masses of chalk are surrounded and nearly enveloped in the sands and clays associated with the crag. These appearances are strictly analogous to the phenomena of Möen above described; but in Norfolk they are on a much smaller scale. In both cases, they compel us to assign a comparatively modern date for an era of partial but violent convulsion, by which the chalk has been deranged.

The projecting mass of solid chalk generally seen at the base of the cliffs, sometimes more than fifty feet high, and sloping like a talus, may perhaps indicate a different rate of movement at which the land rose at different periods from the sea. The elevation after proceeding rapidly for ages may have ceased, so that the waves had time to encroach and shape out a vertical cliff, after which the upheaving process may have been resumed, and what was previously a submarine ledge of rock may then have emerged. What we now see may be the remains of such a ledge, which the sea has not yet had time to sweep away entirely, except in a few places. Or, on the other hand, the rate of emergence of land may have been uniform, and the inferior mass of chalk harder than the upper, in which case it would resist the action of the waves for a longer period. Of this greater hardness however of the lower mass, neither I nor Dr. Forchhammer obtained any proof.

* See his paper published at Copenhagen, Nov. 14, 1835.

XXI.—*Notices and Extracts from the Minute-Book of the Geological Society.*

1.—*Observations on the Cliffs in the neighbourhood of Harwich, made in December* 1832. *By* James Mitchell, LL.D., F.G.S. [Read May 15th, 1833.]

HARWICH is situated upon a peninsula, which is defended from the action of the sea by a promontory on the north-east; and on the east and south-east it is partially protected by walls and lines of posts or groins.

About 300 yards to the south of the light-house begins a cliff consisting of London clay. Where it first appears it is low, but as it projects towards the sea it rises in the course of 300 yards to 35 feet; but for the next 300 yards it recedes from the sea, and declines to the height of 15 or 20 feet. From that spot it again rises to 30 feet, and extends for nearly three quarters of a mile, when it sinks to a level with the shore.

At the point where the cliff is highest, is a small remnant of a battery, which, about twenty years ago, was 30 yards from the edge of the cliff. A whole farm on this part of the coast is said to have been swept away; and within the last twenty-five years a piece of land, called the Vicar's Field, has been totally removed.

At the highest part the cliff presents the following section:

Vegetable soil.	
Chalk flints, rolled pebbles, and clay; the two first predominating	1 ft.
Red clay, in beds, from six inches to four feet thick, and separated by seams of whitish or greenish clay, not calcareous; about	20
Blue "cement marl," or indurated clay, two beds separated by a bed of clay; about	2
Cement stone, consisting of flattened spheroids about three feet in diameter	10 in.
Blue clay, divided into two beds by a whitish streak; about	7 ft.

These measurements were taken by the eye, but the height being small, it is presumed that they are tolerably correct. The lines of stratification are parallel; but, at the point where the section was taken, they are not horizontal, having a gentle anticlinal dip.

A second bed of cement stone is visible on the shore at low water, and about

20 feet in perpendicular descent beneath the first bed*. It appears to be of greater magnitude, as some of the masses are so large that not a crack appears over a surface of 30 feet.

On the top of the cliffs, about 20 years ago, was a patch of crag, which has been entirely destroyed.

In the southern prolongation of the cliff, in that part which extends about three quarters of a mile, the clay is divided by only four whitish streaks, and is nearly the same from top to bottom.

The thickness of the formation in Harwich is inconsiderable, the chalk having been found at the depth of only 60 feet from the surface; and though there is a great accumulation of alluvial matter on the peninsula on which the town stands.

Iron pyrites occur abundantly, and lignite is found, but not in considerable quantities.

Fossils are principally procured from the cement-stone, the most common being a Venus. Nautili are sometimes found, and Mytili with the nacre; also a species of Patella.

The cement-stone, when it first falls from the cliff, is rather soft, but after exposure for some time it becomes very hard. Being of a black colour it is usually mixed with cement made from the Whitstable stone, and is less valuable than the Sheppey. The greater darkness of the colour is attributed to the greater quantity of manganese.

The cliff at Felixstowe, about three miles north of Languard Fort, consists of blue London clay, similar to that at the foot of the Harwich cliff; and on the top is a stratum of crag from 10 to 15 feet thick, the London clay being about 35 feet. No cement stone is seen in the cliff, but at low water, two beds may be found at the same perpendicular distance from each other as at Harwich.

2.—*Notices of the Red Marl and Lias of Worcestershire; of a Fault by which they are affected; and of fossil freshwater Shells at Shotover Hill.* *By* Hugh Edwin Strickland, Esq., F.G.S. [Read December 4th, 1833.]

These notices were accompanied by a manuscript map, on which are laid down, with greater accuracy than had before been attempted, the boundaries of the red marl and lias in the districts adjacent to Pershore, Evesham,

* This measurement was ascertained during the sinking of a well in the fort, on the hill at the south side of the town.

Bitford, Alcester, Droitwich, and Worcester. Mr. Strickland points out, also for the first time, a line of fault ranging from a little north of Bredon Hill, in Gloucestershire, to Inkberrow, north of the road from Alcester to Worcester. By this fault the relative position of the red marl and the lias has been affected, the former constituting a valley of elevation, bounded on each side by the latter. Mention is also made of bones and teeth of the hippopotamus, and of a deer having been found in the gravel near Cropthorne, between Evesham and Pershore. Mr. Strickland likewise alludes to the occurrence, on Shotover Hill, near Oxford, of fossils which he believes to belong to the freshwater genus Paludina; but the specimens which he procured are imperfect casts. These shells, he adds, were first discovered by the Rev. H. Jelly of Bath, in a sand-pit on the brow of the hill, much higher than the pit in which the Portland strata occur.

3.—*Notice of the Analysis of a Mineral Water from the Island of St. Paul, in lat.* 38° 45′ *S., and long.* 77° 53′ *E. By* John Bostock, M.D., F.G.S. [Read January 7th, 1835.]

The Island of St. Paul is stated, on the authority of Capt. Ford, who procured the mineral water, to be of volcanic origin, very rugged in its outline, the highest part being about 700 feet above the level of the sea, and to have the form of a bowl 10 or 12 miles in circumference, into which the sea flows through a narrow opening capable of admitting a boat. The surface of the island is, in many places, covered with pumice; and at night flames issued from various crevices in the rocks. With the exception of the island of Amsterdam, about 40 miles to the north, St. Paul's is at a great distance from any land.

In the hole from which the water was taken the thermometer stood at 212°; and there were numerous other springs, all of which were by the edge of the sea.

Dr. Bostock then explains the manner in which he conducted the analysis; and afterwards compares the results with those obtained by Dr. Marcet from water procured in the middle of the South Atlantic; and infers from the great difference in the mineral contents, that the water of the Island of St. Paul is not merely the water of the neighbouring ocean in a state of dilution or altered simply by mechanical filtration.

Comparative analysis of the water from the middle of the South Atlantic and of that from the Island of St. Paul, lat. 38° 45′ S., long. 77° 53′ E.

Residuum obtained from 100 grains of the water from the South Atlantic.		Residuum from 100 grains of the water of St. Paul.	
Muriate of soda	2·666 grs.	Muriate of soda.....	2·303 grs.
Sulphate of soda	·466	Sulphate of soda	·053
Muriate of lime	·195	Muriate of lime.....	·340
Muriate of magnesia.....	·991	Muriate of magnesia.....	·059
		Loss	·038
	4·118		2·790

4.—*Notice of Fossils found in the Bognor Rocks. By* Woodbine Parish, jun., Esq., Sec.G.S. [Read January 7th, 1835.]

The author, Woodbine Parish, Esq., in a letter addressed to G. B. Greenough, Esq., President of the Society, states that in consequence of the destruction for the purposes of building, of such parts of the Bognor rocks, as are accessible, specimens of Nautilus, formerly abundant, are becoming rare. Together with his communication he forwards a collection and a list of the Bognor fossils.

The author also notices that about a mile to the east of Bognor, and in front of the village of Felpham, chalk is exposed for a considerable distance cropping out of the sands between high and low water mark; and at low water it may be traced for upwards of a mile in the direction of Middleton. It abounds, he states, in its characteristic fossils, of some of which he gives a list. Where the chalk first appears, it is almost as hard as stone, and is thickly interspersed with flints; further on it becomes soft, and the flints are not so numerous.

Chalk marl has long been dug out of the beach near Middleton, at low tides, for manuring the neighbouring beds.

List of Bognor Fossils in the possession of the Geological Society, including those presented by Mr. Parish.

Teredina personata.
Solen affinis.
Pholadomya.
Panopæa intermedia.
Venericardia Brongniartii (?).
Astarte rugata (?)
Cytherea incrassata. (?).
Pectunculus brevirostris.
——— decussatus.
Modiola elegans.
Pinna affinis.
Exogyra.
Ostrea Bellovacina.
Lingula tenuis.
Anomia lineata.
Dentalium planum.
Vermetus Bognoriensis.
Ampullaria (?) sigaretina.

Solarium.	Cassidaria striata.
Pyrula Smithii.	——— carinata.
Fusus rugosus. (?)	Voluta luctator.
Rostellaria Sowerbii.	Nautilus Imperialis.

5.—*Extract from a Letter addressed by* Dr. Daubeny *to the Curator, on a Saline Spring near Oxford.* [Read June 10, 1835.]

"Dr. Buckland having announced to the Society (April 29, 1837,) the existence of the salt spring lately discovered near Oxford, an analysis of the water may perhaps interest the Society, as it contained, when I made my experiments, more sulphuric salts than any other spring in this country, and likewise a certain proportion of iodine. The saline contents in a pint were as follows:—

Chloride of sodium	70·82
——— calcium	7·25
——— magnesium	2·40
Sulphate of soda	52·40
	132·87

Also a proportion of hydriodic acid, yielding of iodine, in the pint, about $\frac{1}{240}$ of a grain. The date of this examination was March 26th (1837), at which time the borings had reached to 280 feet below the surface. Some days later the water was not so strongly charged with sulphuric salts, though the quantity was considerable."

6.—*Notice of a Letter addressed to* Capt. Belcher, R.N., F.G.S., *by* H. Cuming, Esq., *dated March 5th,* 1835, *on the Earthquake in Chili, November 19th,* 1822. [Read December 2nd, 1835.]

The writer arrived at Valparaiso in January 1822, and resided there constantly until 1827, and from the latter period, with occasional absences, till May 1831. At the time of the earthquake, he lived in the Plaza Mayor, near the landing place at the arsenal, and his house was destroyed by the first shocks. He did not go to the beach during the night, but was informed that the sea had retired a considerable distance, and had immediately returned with great force. On the morning of the 20th he noticed the effects, but found nothing more than a high tide. At the time of the convulsion it was dead low water. He never heard of the rocks having been heaved up, or of the permanent retirement of the sea, until the publication of Mrs. Graham's work

on Chili, to the statements contained in which, neither he nor his friends could subscribe.

Mr. Cuming's pursuit of conchology and natural history generally, caused him to visit frequently the rocks and inlets with which the northern and southern parts of the bay abound; but though the rocks were covered with Fuci, Patellæ, Chitons, Balani, &c., yet he never perceived the least difference in their appearance from the date of his arrival to his finally quitting Valparaiso. He mentions particularly, as points which he often examined, the Caleta, the Quebràda de Dios, and the Cruz de Reyes. He also never found the least trace of the above productions, except in situations covered by the tide.

After the earthquake, Mr. Cuming resided in a house in the Arsenal, where the spring tides came up to the same mark as they did previously to that event. He refers especially to the tides of 1822 and 1823.

Another circumstance which convinced Mr. Cuming that no change of level had taken place, was the existence of a small detached rock opposite the Estanco, half-way between the Custom-house and the Market-place, and about fifty yards from the walls at half tide. From this rock he had often taken *Concholepas Peruviana*, previously to the earthquake, and subsequently it retained the same position.

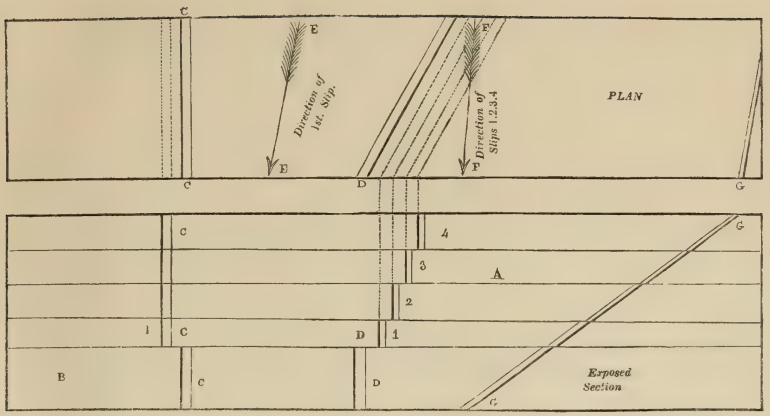
The vessels occupied the same anchorage as they did before November 1822; and nautical men affirmed that there was not the least difference in the depth of the water in any part of the bay.

The opinion that a change had taken place in the relative level of land and sea, Mr. Cuming conceives, originated in the accumulation of detritus at points where the tide flowed anterior to the earthquake, and on which houses and even small streets have been since erected. Though these accumulations appear to have been forming between 50 and 80 years, yet they were small previously to the violent rains in June 1827, which brought down into the bay the loose granitic soil of the hills and the ravines. This detritus has since been thrown up by the tides, and formed into a firm open space exceeding 250 feet in breadth, on which the buildings have been erected. In front of the Custom-house, however, the accumulations were trifling, and the landing place remained in the same state as in 1822.

The quantity of matter thus carried into the bay has not affected the anchorage, and Mr. Cuming, when dredging within two hundred yards of low-water mark, never found a grain of decomposed granite, or any kind of recent soil, but fine sandy mud, well stocked with several species of shells of mature growth.

Both to the northward and southward of Valparaiso, where the coast is open, namely, at Lagunilla, Vina del Mar, Con-Con, and Quintero, the sea has thrown up high banks of sand, many feet above the level of the land behind them, and reaching inland from 1000 to 2000 feet, and at Quintero to a much greater extent. At this place the sand contains beds of shells "in a semi-fossil state," which are burnt by the natives for lime. Mr. Cuming visited these localities previously to the earthquake, and often subsequently, but never saw a shell beyond the range of high water, except those in the state above mentioned, and the owners of the land declared that no change had taken place.

Mr. Cuming also states, that about 70 years since, he believes at the same time that Conception was visited by an earthquake, Valparaiso was also visited. The sea retired to a very great distance, and returned with so great violence that it destroyed all the houses, carrying the boats and canoes to the church of San Francisco, which is about a quarter of a mile, on a gradual ascent from where the tide usually flows.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Exposed Section
G

EXPLANATION OF THE PLATES AND WOOD-CUTS.

PLATES I. & II.

Illustrate Mr. Weaver's paper on the Geological Relations of the South of Ireland: p. 1 to 68.

Plate I.

Contains—(*a.*) View of the mountains on the south of the Blackwater river, extending from the Neagles mountains on the east to MacGillicuddy's Reeks on the west. Taken from Drumskeha, about four miles south-west from Kanturk, and three miles north of the Blackwater.

(*b.*) View of mountain and hilly ranges, from the Mullaghaneesh on the east to the Cahirconrée on the west. Taken from the southern brow of the coal country, about three miles north of the town of Castle Island.

N.B. These two views (*a.* and *b.*) combined, extend through the principal mountain chain in the south of Ireland.

Sections through the South of Ireland.

No. 1. Section from the sea at Loop Head, on the south-west, through the county of Clare to Lough Derg, on the east.

No. 2. Section from the sea at Castle Haven, through the counties of Cork and Kerry to the sea at Kerry Head, from south-east to north-west.

No. 3. Section from the river Maine (Section No. 2.), through the counties of Kerry and Limerick into Tipperary, from south-west to north-east.

No. 4. Section from the sea at Courtmacsherry Bay, through the county of Cork to Broadford in the county of Limerick (Section No. 3.), from south-east to north-west, and from north-west to north.

No. 5. Section from the sea at the entrance of Cork Harbour, through parts of Cork and Waterford to the county of Tipperary, from south-west to north-east.

No. 6. Section through the Dromagh Coal Field, from south to north.

N.B. In the Sections Nos. 1 to 5, objects are, in some cases, projected on the line of section, though they do not stand immediately in the line.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

Plate II.

Contains a Geological Map of the South of Ireland;
Also a Geological Map of all Ireland.

WOOD-CUTS ILLUSTRATIVE OF MR. WEAVER'S PAPER.

Plan and Section of Muckruss Copper Mine : p. 29.

Plan and Section of Ross Island Copper Mine, with the embankment against the Lake of Killarney : p. 30.

Diagram illustrative of the relative position of the properties in the coal district south, west of Kanturk : p. 51.

Plan and Sections of the Annagh Lead Mine, near Castlemaine : p. 64.

N.B. I take this opportunity of noticing, that in the 5th Vol., First Series, of the Geological Transactions, and Plate VII., View No. 4, of my Memoir on the East of Ireland, the words "Keeper mountain" are engraved in a wrong position. They should have been placed over the round topped mountain, which is situated immediately west of the western "Bilboa mountains."

PLATE III.

Map illustrative of Mr. Bryce's Memoir on the north-eastern part of the county of Antrim : p. 69 to 81.

PLATE IV.

Lithographic Drawing of the Squaloraia, described in Dr. Riley's Memoir: p. 83 to 88.

Figs. 1. 2. 3. Magnified representations of a scale. (This plate has been copied, by permission of M. Agassiz, from Table 42, *Recherches sur les Poissons Fossiles.*)

PLATE V.

Illustrates Capt. Bayfield's paper on the Geology of the North Coast of the St. Lawrence : p. 89 to 102.

Fig. 1. Sketch of the River and Gulf of St. Lawrence : p. 89.

Fig. 2. Natural columns of limestone on the east side of Niapisca Island, one of the Mingan Islands : p. 93.

This drawing was made by Mr. Bowen, R.N., not with reference to geological phenomena, but on account of the picturesque beauty of the columns.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

PLATE VI.

Map and contours of ground illustrative of Lieut. Nelson's Memoir on the Geology of the Bermudas: p. 103 to 123.

Fig. 1. General Map of the group, the outline of the reef having been sketched from the usual authorities.

Fig. 2. illustrates contours of ground taken at points without any special selection: the difference of level is indicated by different intensity of tints: pp. 109 & 117.

WOOD-CUTS ILLUSTRATIVE OF LIEUT. NELSON'S PAPER.

Fig. 1. & 2. Sections at the summit of Retreat Hill, St. George's Island. The waved lines mark the disposition of the layers of sand: p. 106.

Fig. 3. & 4. General sketches of the cliffs along the south side of Bermuda, or the Main Island: p. 107.

Fig. 5. Section across the east end of Ireland Island: p. 108.

Fig. 6. Section at right angles to *a*. Fig. 5. The difference in the direction of the dip indicating the former existence of mantle or saddle-shaped strata: p. 108.

Fig. 7. Caverns covered by red earth: p. 108.

Fig. 8. Cave once under the North Bastion, Ireland Island: p. 112.

Fig. 9. Sections through a supposed fossil palmetto grove. The parts marked *a* are filled with hard compact stalagmite: p. 115.

Fig. 10, *c* and *d*. Plan and section of the recent palmetto root: p. 115.

Fig. 11. Plan of a coral reef forming around a sand-bank: p. 116.

Fig. 12. Section of a small isolated coral reef: p. 116.

Fig. 13. Plan and section of a serpuline reef near Elbow Bay, south side of Bermuda: p. 117.

Fig. 14. Section near the Magazine Pond, Ireland Island, illustrative of one of the first steps in the formation of caverns: p. 118.

Fig. 15. Sand caves: p. 119.

Fig. 16. Pinnacles near Tobacco Bay, St. George's Island: p. 120.

PLATE VII.

Map and Sections illustrative of Mr. Romley Wright's paper on the Brown Clee Hill: p. 125 and 126.

PLATES VIII. & IX.

Fossils from the well sunk at Hampstead, and described in Mr. Wetherell's paper: p. 131 to 136.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

Plate VIII. p. 136.

Fig. 1. Desmophyllum.
Fig. 2. Pennatula.
Fig. 3. Pentacrinus subbasaltiformis.
Fig. 4. ———— Sowerbii.
Fig. 5. Pollicipes (?).
Fig. 6. Tellina splendens.
Fig. 7. Lucina Goodhalli.
Fig. 8. Venus tenuistriata.
Fig. 9. Arca nitens.
Fig. 10. —— impolita.
Fig. 11. Nucula Bowerbankii.
Fig. 12. ——— Wetherellii.
Fig. 13. ——— striata, *var.*
Fig. 14. ——— compressa.
Fig. 15. Avicula arcuata.
Fig. 16. ——— papyracea.
Fig. 17. Dentalium anceps.
Fig. 18. Scalaria undosa, *var.*
Fig. 19. Ovulum retusum.

Plate IX. p. 136.

Fig. 1. Cytherina barbata.
Fig. 2. Pollicipes (?).
Figs. 3. 4. 5. 6. 7. Nodosaria.
Figs. 8. 9. Articulina.
Fig. 10. Articulina ?
Fig. 11. Frondicularia ?
Fig. 12. Marginulina.
Figs. 13. 14. 15. 16. 17. 18. Rotalia.
Fig. 19. Cristellaria.
Fig. 20. Miliola.
Fig. 21. Cellepora.
Fig. 22. Flustra ?

PLATE X.

Map and Sections illustrative of Mr. Prestwich's paper on the neighbourhood of Gamrie : p. 139.

The Map extends along the coast from White Hills to Trouphead. The dotted portion represents gravel and other superficial detritus.

Sections—No. 1. Is the coast section from Blackpots to Banff. The horizontal scale of this and the other sections is four times that of the Map.

No. 2. Cliff of Gamrie Bay : pp. 140. 145.

No. 3. From Gamrie to near Afforsk : p. 145.

No. 4. Section of the superficial detritus at Castle Hill, near Gamrie : p. 146.

WOOD-CUT.

Section of the strata containing Ichthyolites at the ravine near Mr. Dockar's house, Finden : p. 142.

PLATE XI.

Map and Sections explanatory of Archdeacon Verschoyle's paper on the north coast of Mayo and Sligo : p. 149 to 170.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

WOOD-CUTS ILLUSTRATIVE OF THE PAPER.

No. 1. Shifted quartz veins in a perpendicular cliff at Mycreeny, between Blind Harbour and Erris Head : p. 158.

No. 2. Diagram explanatory of No. 1. The portion folded back is intended to represent the surface, at the top of the cliff; and the other part of the diagram the cliff as represented in No. 1. In using the diagram, the portion folded back should be held at right angles to the other : p. 159.

No. 3. Strata of mica slate bent over projecting masses of trap at Attatovick Point : p. 162.

No. 4. Contorted strata of shale and grit, north of Poolaclogher : p. 165.

No. 5. Trap dyke in carboniferous limestone east of Killala Bay : p. 167.

PLATE XII.

Illustrates Mr. Broderip's memoir on some fossil Crustacea and Radiata found at Lyme Regis : p. 171 to 174.

Figs. 1. 2. Coleïa antiqua : p. 172. *Fig.* 1. represents a young individual in the collection of the Geological Society.

Fig. 2. *a.* Peduncle of mesial antennæ.

b. Internal setæ.

c. External setæ.

d. Lamelliform appendage of the peduncle of the external antennæ.

e. Base of the terminal setæ of the external antennæ.

Fig. 1. *f. f.* Eyes.

Fig. 1. 2. *g. g.* Thorax.

Feet.

First pair or *chelæ*, which have been displaced in both specimens, and pushed forward in the smaller one.

Fig. 2. *h.* Humerus.

i. Cubitus.

k. Carpus.

l. Manus.

m. Digitus.

n. Pollex.

Fig. 1. *o. o.* Indications of the other feet, shown by the partial removal of the thorax.

p. Post abdominal segments.

q. q. Caudal natatory lamellæ.

Figs. 3. 4. Remains of a macrourous Decapod, allied to the Salicoques of Latreille : p. 173.

a. a. Point to the impressions of the branchiæ, exposed by the removal of the lateral portions of the thorax.

b. b. Terminal spines of the post abdominal segments.

Fig. 5. Ophiura Egertoni from the collection of Mrs. Murchison. The figure repre-

sents the inferior or ventral aspect of the animal; in consequence of weathering, the external surface is gone, leaving an internal view of the disk and arms: p. 174.

Fig. 6. Represents the external surface of the dorsal aspect of an arm of the same species, found by Lord Cole, and in his possession.

Fig. 6*. Three magnified segments of the same.

N.B. The arms in the specimen, figure 5, are truncated, but there is no doubt that in this, as well as in the other species, the arms were continued to a great length, till they terminated in a very fine point.

PLATE XIII.

Description of the Plate accompanying Mr. Mantell's memoir on the Fossil Bones of Birds, discovered in the Strata of Tilgate Forest: p. 175.

Fig. 1. *a.* The anterior; and *fig.* 1. *b.* the posterior aspect of the lower extremity of a left tarso-metatarsal bone of a bird. At *o* is seen the elliptical rough surface denoting the place of attachment for the posterior or opposable toe; and it is situated at such a distance above the other toes as to prove that the bone belonged to a *wader*, and not to an insessorial or a raptorial species. The dotted outline represents a restoration of the inferior extremity of the bone, which is wanting in the fossil; probably, as Mr. Owen has suggested, from the bird having been young, and the epiphysis not anchylosed.

× *Fig.* 1. *b.* Marks the longitudinal ridges for the attachment of the aponeurotic thecæ, which tie down the tendons as they glide along the metatarsus to the toes.

Fig. 2. Posterior view of the left tarso-metatarsal bone of a heron (*Ardea cinerea*) for comparison with the fossil: *o* marks the place of attachment of the opposable toe.

Fig. 3. The proximal extremity of a bone which was found with *fig.* 1. in the same block of sandstone, and is so similar to the latter, both in colour, surface, and substance as to appear like the other extremity of the same bone. Mr. Owen considers it to be the proximal end of a tibia of a bird.

Fig. 4. The distal extremity of a tarso-metatarsal bone, and the bones of the toes of a heron, to illustrate the nature of the fossil specimens.

Fig. 5. *a.* A fragment of a bird's bone imbedded in sandstone, showing a longitudinal groove. *Fig.* 5. *b.* represents a section of one extremity.

Fig. 6. The tarso-metatarsal bone of a bird imbedded in Tilgate grit. This specimen was carefully examined by Baron Cuvier, who confirmed the opinion of the author of its belonging to some species of *Grallæ*.

WOOD-CUTS

Explanatory of Mr. Griffith's memoir on Syenite Veins in Mica Slate and Chalk, at Goodland Cliff and Torr Eskert, county of Antrim: p. 179 to 185.

No. 1. Section exhibiting the geological structure of the country from Fair Head to East Torr: p. 179.

Nos. 2. 3. Syenite veins passing through mica slate in Goodland cliff, south of Murlough

Bay. In *No.* 3. a third vein is represented, interposed between the two principal veins: p. 180.

Nos. 4. 5. Connexion of chalk and syenite at Torr Eskert: pp. 183, 184.

PLATE XIV.

Illustrates Sir Philip Grey Egerton's memoir on certain peculiarities in the cervical vertebræ of the Ichthyosaurus: p. 187 to 193.

[All the figures are of the natural size except 9 and 10, which are reduced to one half.]

Fig. 1. Atlas of an Ichthyosaurus.
- *a.* Occipital socket.
- *b.* Articulating surface for the first subvertebral bone.

Fig. 2. Side view of *fig.* 1.
- A. The atlas.
- B. The axis.
- *a.* Surface for the insertion of ligaments.
- *b. c. f. g.* Planes for the articulation of the subvertebral bones.
- *d.* Articulation of the first rib.

Fig. 3. Atlas and axis disunited.
- *a.* Articulating surface for the first subvertebral bone.
- *b.* Second subvertebral bone in situ.
- *c.* Articulation for the first rib.

Fig. 4. Upper view of the first subvertebral bone.
- *a.* Surface articulating with the atlas.
- *b. b.* Anterior alæ.
- *c.* Socket embracing the lower circumference of the occipital tubercle.
- *d.* Plane abutting against the second subvertebral bone.

Fig. 5. Under view of *fig.* 4.
- *a.* Central boss of bone.

Fig. 6. Lateral view of *fig.* 5.

Fig. 7. View of the cervical portion of an Ichthyosaurus.
- *a.* Basilar element of the occipital bone.
- *b. c. d. e. f.* Cervical vertebræ.
- *g. h. i.* Three subvertebral bones.
- *k. l.* Sockets for the first and second subvertebral bones.

Fig. 8. Three subvertebral bones seen from below.

Figs. 9. 10. Cervical vertebræ of a large Ichthyosaurus, reduced half.
- *a. a.* Intervertebral cavity. *b. b.*, *c. c.*, Alternate elevations and depressions of the articulating surfaces of the bones fitting into each other.

Fig. 11. Third cervical vertebra of a small Ichthyosaurus.
- *a.* Articulation for the third subvertebral bone.

Fig. 12. Atlas and axis of *Ichthyosaurus tenuirostris* from Street, in Somersetshire.
- *a.* Articulation for the first subvertebral bone.
- *b.* Second subvertebral bone *in situ.*
- *c.* Sharp edge of the axis, showing the non-existence of the third subvertebral bone in this species.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

PLATE XV.

Map and Sections illustrative of Mr. Maclauchlan's memoir on the Forest of Deane. The scale is the same as that of the Ordnance Map: pp. 195 to 206.

WOOD-CUTS.

Diagram to explain the contortion in the Coal Measures near Lidbrook Valley: p. 201.
Diagram of part of the great fault between Lydney and Denbigh Lodge: p. 205.

PLATES XVI. & XVII.

Illustrate Mr. Stokes' memoir on a piece of Wood, partly petrified by carbonate of lime; with some remarks on Fossil Woods: p. 207 to 214.

In Pl. XVI. *Fig.* 3. and Pl. XVII. *Fig.* 1. the dotted lines indicate the portions presented in the magnified figures, Pl. XVI. *Fig.* 4. and Pl. XXII. *Fig.* 2.

WOOD-CUT.

Partially petrified Wood from the Vale of the Aire, near Ferrybridge, Yorkshire: p. 211.

WOOD-CUT.

To illustrate Mr. Hunton's remarks on the distribution of Fossil Testacea in the Upper Lias and Marlstone of Yorkshire: pp. 215, 221.

PLATE XVIII.

Fossils of the Faxoe Chalk: noticed in Mr. Lyell's Memoir on Seeland and Möen: p. 243 to 257.

Fig. 1. 2. 3. Cypræa bullaria (Cyprecites bullaria Schlotheim) from a drawing supplied by Dr. Beck: p. 250, note.

Figs. 4. 5. 6. & 7. Nautilus Danicus, (Schlotheim.) *Figs.* 4. & 5. From drawings supplied by Dr. Beck. *Figs.* 6. & 7. From a specimen in the Geological Society's Museum: p. 250, note.

WOOD-CUTS.

Fig. 1. Valve of a Venericardia resembling V. senilis of the Crag: p. 245.
Fig. 2. Section in the Cliff near the church of Hoierup, Stevensklint: p. 247.
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Fig. 7. Section of a chalk cliff near a rock called Taleren, Möen: p. 254.
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Fig. 10. Section of a promontory between Taleren and Sommerspiret, in which a mass of blue clay intersects the chalk: p. 255.
Fig. 11. View of the Cliff called Dronningestolen, Island of Möen: p. 256.

TRANSACTIONS

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SECOND SERIES.

VOLUME V.

PART THE SECOND.

Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant.

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XXXII. *Letter from Mr.* James de Carle Sowerby *to the Secretary, on the Genus Crioceratites and on Scaphites Gigas.* . . . . p. 409

The Third and concluding Part of the Volume being nearly ready, will be published in February, and will contain the following Memoirs :—

Prestwich on Coalbrook Dale ; Fox on Mineral Veins ; Cautley and Falconer on the Astragalus of a Fossil Monkey ; Darwin on the Formation of Mould ; Owen on the Tail of the Ichthyosaurus, and on the Plesiosaurus Macrocephalus ; Malcolmson on India ; Bell on Mazunderān ; Hamilton on Asia Minor ; Strickland on Sandstone Dykes ; Darwin on Earthquakes ; Sedgwick and Murchison on Devonshire ; Stokes on Orthocerata ; and Sykes on Cutch Fossils. List of Donations and Index.

CORRIGENDA.

Page 302, *line* 7, *for* Turbinella *read* Turbinellus.
Page 348, *line* 4, *for* destructive *read* distinctive.
Page 353, *line* 6, *from bottom,*
Page 354, *line* 7, } *for* Plate XXIV. *read* Plate XXIX.

XXII.—*On the Structure of the Sevâlik Hills, and the Organic Remains found in them.*

By PROBY T. CAUTLEY, Esq., Capt. Bengal Artillery, F.G.S.

[Read March 9, 1836.]

THE mountains, a part of which I am about to describe, range (with the exception of the debouchures of rivers) almost uninterruptedly from the Sutluj, which separates the territory of the British Government from that of the Sikh chieftain, Runjeet Sing, to the Burhampootur river, and the district of Cooch Behar. Their general bearing, in the portion near the Sutluj*, is N.W. and S.E.; but in that approaching the Burhampootur, it is many points nearer direct east and west. They lie at the foot of the great Himalayan chain, with which they are in some parts connected by a succession of low mountains; but in others, as in the districts under review, they are separated by valleys from three to ten miles in width, and called by the natives Deyra Dhoon, Kearda Dhoon, &c., or the Valley of Deyra, the Valley of Kearda, &c. The highest peaks do not far exceed 3000 feet, and the generality of the summits vary from 2000 to 2500 above the level of the sea. It is necessary, however, to premise, that my observations have not extended further eastward than the Ganges; and that whatever I may record, in this paper, beyond that river, is given on the authority of others.

Between the Ganges and Jumna rivers, this line of mountains is separated from the great chain of the Himalayas by the Dhoon, or valley of Deyra, the average width of which may be under ten miles. At the Ganges, or south-eastern extremity, a road passes between the chain and the river; and no difficulty whatever is offered to the approach to the valley. At the opposite or Jumna extremity, on the contrary, the mountains are in many places scarped into the river; and the footpath used by the boat and raft people, is an irregular track, over ridge and through hollow, and impinges upon the river at

* Plate XIX. Map.

those points only where the stream, in its meandering course, strikes the opposite side of the channel. The intermediate roads, or ghàts, follow the rivers or hill-streams; for in such an utter confusion of mountains, any other passage is impossible. A few of these roads are passable for wheeled carriages, but the generality are bad footpaths. Between the Jumna and the Sutluj are two other valleys, the Kearda and the Pinjore, separated from each other by one of those complex masses of mountains which connect the lower with the upper Himalaya range. The hills are generally less precipitous in this neighbourhood; and the higher points and ridges are separated by valleys, affording a drainage to the country, and displaying on each side high and beautiful sections of the stratification. These valleys, or plateaux—for, with reference to the rivers running below them, they may be considered as such—vary in width, but extend along the whole course of the mountain-streams.

As much confusion may be avoided, in the absence of a native name for the whole range of these mountains between the Sutluj and the Burhampootur, by establishing one, which may be considered legitimate, I wish to propose that of Sevâlik*, formerly applied to the portion between the Ganges and the Jumna; a name which appears to me better than that of the "Lower Hills" or the "Sub-Himalayan," terms, equally applicable to the subordinate ranges northwards of the Himalayas.

These preliminary observations, with the appended sketch of the country†, will make the reader acquainted with the field of our fossil discoveries; and I proceed to the description of the geological features of the tract. The for-

* In Smith's Exotic Botany, vol. i. p. 9., is the description of the *Rhododendron arboreum*: he refers it "to the mountainous tract called the Sewalic chain, which separates the plains of Hindostan, between 75° and 85° E. long. from the Himalaya mountains. I make the quotation for the value of the name, though the statement is evidently wrong; the rhododendron in question growing in the Himalayas themselves at a high elevation, and in company with oaks. The chain separating the plains of Hindostan from the Himalayas, which is the one now under review, is subject to a mean temperature perfectly inimical to oaks and the *Rhododendron arboreum*. The name is quoted also in Dow's History, and in some traditional writings in the possession of the high priest or Mahant residing at Deyra. The derivation supplied by the high priest is as follows:—

"Sewalik, a corruption of *Shibwalla*, a name given to the tract of mountains between the Jumna and the Ganges, from having been the residence of Ayshoor Shib, a name of Mahadeo and his son Gun, who, under the form of an elephant, had charge of the westerly portion, from the village of Doodhli to the Jumna; which portion is also called Gungujur (*gujur*, elephant): the portion eastward from Doodhli, or between that village and Hurdwar, is called Deodhar, from its being the especial residence of Deota, or Ayshoor Shib. The whole tract, however, between the Jumna and the Ganges, is called Shibwalla, or the habitation of Shib."

† Plate XIX. Map.

mations composing the hills, consist of beds of boulders or shingle, either loosely mixed or agglutinated by clay and carbonate of lime; of sands of various degrees of consistency; of marl or clay conglomerate*; and of an infinite variety of clays; the two latter being most extensively developed to the westward of the Jumna. The strata dip from 15 to 35 degrees, generally towards the north; and the breadth of the inclined beds is from six to eight miles.

The succession of the strata is irregular, with the exception of the shingle in the more northern tracts, where it appears to overlay as well as to alternate with the sandstones; whereas, although the debris is in considerable abundance in the water-courses, and on the flanks of the hills, I have never met with these shingle-beds south of the most northern half of the hills. A similar remark applies to the marl, but in a contrary direction, as it occurs only to the south. The want of the marl in the northern sections may be accounted for, by supposing it to have been either a local deposition or a general one, which is not exposed throughout its entire range.

Although I consider the whole of this tract of mountain as composed of one formation, it may be of use to divide the portion between the Jumna and Ganges, from that westward of the former river, as it appears to me, that there is a marked difference (as before stated) in the shingle strata, as well as in the position and number of the clay beds; although perhaps nothing further than would be exhibited on any extended line of country, formed of debris from different tracts of mountains. The causes which upheaved this district, apparently acted more energetically in the contracted surface eastward of the Jumna, than in that to the westward; though, in the latter, the surface upheaved is much more extended. I shall therefore divide these notes into two sections; the first consisting of the tract between the Jumna and Ganges; the second, that westward of the Jumna. To commence, therefore, with the range between the two rivers.

Hills between the Jumna and Ganges.

Shingle and Sandstone.—The beds of shingle are of enormous thickness, and alternate with the sandstone. The former precisely resemble the shingle in the beds of the existing great rivers of the country, and consist of boulders

* I call this stratum clay-conglomerate, the beds being composed of fragments of an indurated clay, cemented together by clay, sand, and carbonate of lime; the clay itself effervescing strongly with acids. The rock is, in general, exceedingly hard and tough, as is shown in those parts where it is in contact with the stream of the rivers, which appear to have had little power upon it.

of granite, gneiss, mica slate, quartz, hornblende schist, and traps; and every other rock, through which these rivers hold their course. If the beds of the Jumna and Ganges were to be upheaved, in the same way as those of former rivers, the appearance of the strata would be exactly similar. The sandstone consists either of grains of pure quartz, with different proportions of mica, or of an admixture of the other ingredients so common in all river sands. The presence of oxyd of iron causes a great variety in colour, from red to gray, whilst the induration of the rock appears to depend on the proportion of carbonate of lime. In the more easterly limit opposite Hurdwar, as well as other places, the stone is quarried for building; and in many localities where it is crystalline, it is highly valuable in architecture. On the Jumna are the remains of an ancient hunting palace, built by the emperor Shah Juhan at the end of the 17th century; and although now in utter ruin, amongst its fragments are capitals of columns, and scolloped arch work, &c. cut in this sandstone, which prove it to be well adapted for architectural purposes. It is easily worked, and the mixture of mica gives two splitting surfaces. On exposure to weather, however, it exfoliates and crumbles, as is conspicuously shown in some lintels, still in position at Badshahmuhul. The colours of the clays are endless; and a light blue variety, which is found under the marl, as well as higher up in the series, where it contains fresh-water shells, is exceedingly pure. The strata of this blue clay are thin, but those of the other varieties are of all dimensions.

Lignite.—Carbonaceous matter occurs throughout the sandstones, either in detached fragments exhibiting vegetable origin, or in strata or seams composed of sandstone and lignite in equal proportions. Lignite is also found in the marl, but generally in the form of black dust; leaving, on its removal, an indistinct, vegetable impression. In one instance, I also met with it in the shingle strata. It has never been found in sufficient abundance to excite an inquiry as to its adaptation for œconomical purposes; though it is common to the whole of this tract of mountains. Eastward of the Ganges it has been found, to the north of the Moradabad district; and it agrees in every respect with that found elsewhere. It has also been met with at points still more easterly; but the examination of that tract has been very slight. The most interesting point at which I have found lignite, is at the mouth of the Kalowala Pass, one of the entrances into the Deyra Dhoon, from the plains. A stratum or bed of yellow and red sand, about 18 inches thick, is there completely charged with lignite, either in long flattened masses, or in transverse sections of trunks of trees, which show, by their elliptical form, effects

of vertical pressure. The lignite, in these cases, constitutes merely the outer covering; the interior of the trunk being composed of the sandstone matrix. The bed is enveloped in strata of the marl, abounding in the remains of animals; and both the lignite bed and the marl, appear at this point most distinctly to have been deposited in a hollow; the beds, at their lateral extremities gradually attenuating, until they meet the sandstone rock; and the lower surface being concave. Although the marl is evidently limited at this spot, it seems to exist so generally in extended strata, that, supposing it to have formed tracts of marsh land, those tracts must have been very extensive. I have before remarked, that I have seen the marl only on the southern limits of these hills, between the Jumna and Ganges. In crossing the former river, however, the same stratum, with the same organic remains, is met with on the north of the mountain ridge, on which the town of Nahun stands. Here the upheavement has been more violent than elsewhere; and the point of junction of this tract with the higher Himalayas is consequently much dislocated. It is necessary to state, that there are appearances of trap* in the neighbourhood of these disturbances; a fact which may lead hereafter to an interesting geological disquisition on the point of junction. Fossil wood, apparently *dicotyledonous*, abounds in the sandstone. The woody fibre is generally perfect, but impregnated with the sandstone, and frequently mixed with carbonaceous matter; in which case the fossil is black, and on fracture has the appearance of an intimate mixture of coal and sand, or of an imperfect coal. The only remains of animals yet found are fragments of tortoises.

Marl, with Organic Remains.—As the marl is in greatest abundance in this section, I will now give an account of its organic remains; confining myself to classes and genera. These fossils are in appearance perfect, and the deep black colour which they have derived from hydrate of iron, renders them ornamental. The medullary cavities are, in many cases, filled with pyrites, and in others with pure white crystallized carbonate of lime. The greater part of the fossils, already procured, is from the deposit in the Kalowala Pass; and as my collection is not only large, but abundant in different genera, the number already found in such a limited space, indicates the great variety of animal remains, which a diligent and extensive search may produce. Teeth, and the more solid part of the bones, are found in the greatest quantity. Most of the former are perfect, and as sharp in their outline as when the animals existed; and even in the fragments, the sharpness of the fracture

* Dr. Falconer has made the same observation. Journ. Asiatic Soc. Bengal, vol. iv. p. 50; date of communication, 3rd Jan. 1835.

proves, that they were quietly deposited in the sediment in which they are found. The following is a list of the fossils already discovered in the marl:—

Mammalia.

Pachydermata - - Teeth, and the remains of a species of *Anthracotherium*.
Carnivora - - - Genera doubtful; but some of the teeth correspond with the third incisor of the bear.
Rodentia - - - Rat, and a small variety of castor.
Ruminantia - - - Deer, several varieties, and one molar of a very small species.
Solipeda - - - Horse, one incisor, and one molar from the right side of the upper jaw: they exhibit a peculiarity in the form of the enamel flexures.

Reptilia.

Crocodilia - - - *Ghariâl.* (*Gavial* of naturalists.) Teeth and bones in abundance.
Crocodile. Teeth, in great abundance, fragments of the osseous plates, vertebræ, and other bones.
Chelonia - - - - *Emys.* Fragments of the plates of the back very perfect; also ribs, with the attached osseous part of the buckler.
Tryonix. Ditto, ditto. Some marked differences in the form and position of the rugous surface of the fragments of the buckler, may hereafter point out a variety of species.

Pisces.

Vertebræ and Scales—The latter doubtful.

Testacea.

Bivalve - - - - Imperfect, but resembling *Unio*. *Univalve*: a cast resembling that of the *Paludina* of the present fresh-water*.

Besides these more easily determinable remains, there have been found a number of incisor teeth, which I cannot assign to any genus; also quantities of bones, in fragments, and portions of ribs, one of which must have belonged to a large animal; also vertebræ, metatarsal or carpal bones, &c. With the exception of the teeth, the remains are generally in fragments, and separated; nor does it appear probable that we shall meet with anything approaching to a complete skeleton.

In the tract then between the Jumna and Ganges, the fossil remains as yet discovered are thus disposed:—

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* The only univalve which has been yet found in the marl is the cast above-mentioned, from the rock north of Nahun. I have entered it here, considering, as I do, that the deposits are identical.

Shingle, or Gravel Beds—Lignite, scarce.

Sandstone - - - - Trunks of dicotyledonous trees in great abundance; lignite, and remains of reptiles.

Marl - - - - - Remains of mammafers, reptiles, fishes, shells, and lignite.

The mineral products are, carbonate of lime, the general cement of the whole formation, also in stalactites and stalagmites; selenite, in small tabular crystals; and pyrites, but apparently in the neighbourhood of organic remains only. Soda abounds throughout the mountains, efflorescing on the shingle and sandstone rocks; and the presence of this alkali may explain the partial disintegration of the boulders of which the shingle is composed: for, I believe, I am right in asserting, that every variety of boulder, from granite to quartz and sandstones, has been acted on: and when it happens that the boulders can be removed entire from the bed, they fall to pieces, either after exposure to the air for a time, or by pressure of the hand immediately. With regard to fractures in some of the boulders, and their consolidation on different planes, as in a slip of stratification, no remark whatever appears requisite, as these are the necessary consequences of that movement, which raised the beds from their horizontal position. There does not appear to be any further remark necessary on this tract, more than can be reserved for the general summary; I shall therefore proceed to describe the hills westward of the Jumna.

Hills West of the Jumna.

These, as I before stated, consist of the same series of shingle, sand, clays, and marls; but they differ, in the beds of shingle being less abundant, although equally inclined, and in containing a different description of boulder. The rolled fragments eastward of the Jumna are all of primary or lower rocks, whilst those to the westward are confined to varieties of clay slate, and quartz. The marl, which, between the Jumna and Ganges shows itself in the southern limits, is here exposed at a point north of Nahun, cropping out on the northern slope of the mountain; and the fossil remains resemble those found in the marl eastward of the Jumna, consisting of mammafers, crocodiles, tortoises, fishes, and shells. From Nahun to the plains there is a succession of sandstones and clays, without any abundance of shingle. The sandstone, which, in the vicinity of Nahun, is much indurated, and used for building, becomes softer on approaching the plains; long before reaching which, the whole formation consists of an interminable succession of sandstones and clays, the latter being in the greatest abundance, of every variety of colour, and

dipping, on an average, 20° to the north. The topographical outline of these mountains, shows a considerable southing of upheavement, in the hills westward of the Jumna, as will be observed in the map*: and the circumstance of the fossil remains abounding in the sandstones and clays in this tract, and not in that between the Jumna and the Ganges, may probably be due to the non-upheavement of the line on its prolongation eastward of the Jumna. The drawings which accompany this paper† show that the action, in all probability, was exerted irregularly; and although in the large scale we may lay down the dip and direction with accuracy, the former as varying from 15° to 35°, and the latter from N.E. to S.W., local details give very different results.

The sandstone rock, from which the fossil remains sent to the Society's Museum were extracted, reposes at the above angle, over numberless beds of clays, more or less rich in testaceous remains. The fossil bones lie in great abundance on the surface of the slopes in the neighbourhood of the sandstone, amongst the ruins of fallen cliffs, in the beds of water-courses, &c. The bones which we have had the good fortune to dig out of the rock are perfectly sharp, and in all their original perfection. I may here advert to a circumstance to which the preservation of the water-worn specimens is chiefly due. The sandstone is generally soft, but in the proximity of the fossils it becomes ferruginous, concretionary, and so hard as to turn the edge of the chisel; and thus protects the fossil from destruction in its progress, as a boulder along the torrent's bed. These concretions are occasionally globular, and become singularly conspicuous, by the weathering of some of the ridges, when the mass of rock takes the appearance of huge spherical concretions piled confusedly on each other.

The organic remains of this sandstone yet brought to light, belong to the following classes and genera: most of the species are new; and the appearance of totally undescribed forms will add very considerably to our fossil genera. The new genera themselves will be the subject of separate accounts in their proper place.

Mammalia.

Pachydermata -	Mastodon—elephant—rhinoceros—hippopotamus—hog.
Carnivora - -	Canine and feline.
Ruminantia - -	Elk—ox—deer in great varieties.
Solipeda - - -	Horse.

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* Plate XIX. † Ibid., fig. 1 to 4.

Reptilia.

Crocodilia - - Ghariâl—crocodile; both very closely corresponding with the existing species now in the rivers. Lacertine remains indeterminable.

Chelonia - - Emys and tryonix; some of the fragments are of the most gigantic proportions. Of the smaller varieties, nearly entire specimens have been found; upper buckler and carapax complete. My cabinet also contains three heads, wanting only the occipital portion of the cranium.

Pisces.

Genera not established.

Many other fragments have been found, but so imperfect as to render a classification impossible. I may remark, that there appears to be no end to the variety as well as quantity of these remains; and we may expect to do much, even in this remote region, in advancing the inquiries respecting fossil zoology.

Of each genus above mentioned, with the exception of the horse and the carnivora, I have already almost perfect skulls. The bones of the body, however, appear to have been much broken and mutilated; but it is a singular fact, that from many places where the fossils have been found as mere debris of fallen cliffs, fragments of bone have been obtained, which have admitted of being joined, although the fractured ends were coated with carbonate of lime, as if they had been fossilized separately. A beautiful example of this, is exhibited in an almost perfect rib of an elephant or mastodon, which is forwarded to the Society's Museum, and which consisted of no less than eight pieces. A perfect humerus of a ruminant has been secured in this state; and the bones of two hind legs, namely, the upper part of the metatarsal connected to the lower portion of the tibia by the intermediate tarsal bones, with, also, the os calcis entire, and all the smaller bones of the tarsus equally so. These remains have belonged to an enormous animal, and, I believe, to the same genus as that of a skull in my possession, and now under description by my friend Dr. Hugh Falconer, of the Bengal medical service, and myself. Although I refrain from zoological details, I must mention, that we have an animal evidently forming a connecting link between the *Pachydermata* and *Ruminantia*, or between the *Tapir* or *Palæotherium*, and the latter order of mammalia. The hippopotamus of this sandstone appears to be a new species, having six incisive teeth, besides other peculiarities, particularly in the proportion of the bones of the head: the tusks also differ from those described by Cuvier in his Ossemens Fossiles. The great depth at which the marl lies beneath the upper strata, with the discovery in it of remains of the horse, is an interesting fact. In the sandstone strata the remains of the horse are

by no means scarce. There appears, however, to be a local disposition in the deposits of these remains. In some places the hippopotamus, elephant, mastodon, crocodile, tortoise, &c., are found in abundance, with the remains of ruminants; in others the hippopotamus and the water reptiles are almost totally absent, and only the remains of ruminants and carnivora occur; all tending to prove that these animals were destroyed on the site of their habitats; and that this former world was not more mysterious than the present; that there were vast tracts of marsh and river, with their attendant hippopotami and crocodiles in the waters, and elephants and mastodons in the neighbourhood; and that there were other tracts free from water and marsh, and frequented by their natural inhabitants, ruminants, carnivora, &c.

Dr. Falconer, in a note read at a meeting of the Asiatic Society of Calcutta*, suggested the identity of this deposit with that near Prome, some of the fossils from which have been so beautifully lithographed in the Society's Transactions†. The mastodons in the Sevâlik strata are in great abundance; and as we have perfect skulls, we are enabled to form some opinion of the dentition and the change of teeth. Three of these skulls, now in my cabinet, have the front tooth worn, and the rear one coming into use; the whole line of teeth stretching on a surface of 19 inches, and forming an arc of 90°. The *front* tooth I cannot distinguish from that of the *M. Latidens* figured in the Geological Transactions; and the *rear* one, in the same animal, bears such perfect resemblance to the *M. Elephantoïdes*, that I cannot help risking the conjecture that the *M. Latidens* and the *M. Elephantoïdes* are one and the same animal; the specimens, from which the specific characters were taken, having been detached teeth.

Bringing this forward in the way of suggestion may be of use, in ultimately leading to truth. The question, however, must be determined by a strict examination of specimens; and having advanced the above supposition, I will take care that the means shall be provided‡.

* Journal Asiatic Society, vol. iv. p. 58; date of communication, 3rd January 1835.

† Geological Transactions, 2nd Series, vol. iii. p. 377 *et seq.*; pl. 36 to 43.

‡ The rear or newly-formed teeth of every species of mastodon resemble those of the elephant, so far as relates to the integrity of the apices or summits of their transverse ridges; and they might therefore be mistaken for those of the *M. Elephantoïdes*; but the observations which led to the conclusion, that the Ava specimens of mastodon belonged to two distinct species, were not made on detached teeth. A repeated examination of the jaws and teeth described by Mr. Clift, and the knowledge that his opinion was formed from considering the size and number of the transverse ridges in relation to the length and breadth of the teeth, have tended to confirm my belief in the establishment of two species, which I must retain until further and more definite evidence to the contrary is adduced.—Referee.

The minerals in this tract, west of the Jumna, correspond with those to the eastward, with the exception of the presence of the gold, which occurs in the beds of the rivers in these mountains, both eastward of the Ganges, and westward of the Jumna; but I am not aware of its existence in the intermediate tract. Under Nahun, gold-washers are constantly employed during the dry months; their daily return varying from two annas to two rupees, or from 3*d.* to 4*s.* The process is extremely rude. A piece of board, a long wooden trough, a ladle made out of a gourd, a sieve of the large grass which grows so abundantly in this part of the country, and a piece of hollow bamboo with a little quicksilver, constitute the portable apparatus of these most primitive washers for the precious metal*. A great deal of the gold-dust must necessarily be lost by this method of proceeding; and all the mercury, as it is evaporated in open air. The grains of gold are not larger than the small scales of mica, so common in river sand; and I have not heard that the metal has been found in large masses. This gold, too, has its localities, some streams being much richer than others. Where is the fountain head? In some stratum of this alluvium, perhaps, yet to be discovered, as the streams have no connexion with the higher mountains. A description of the washers, and the method practised by them eastward of the Ganges, have been given in the Journal of the Asiatic Society; and as there is little difference in the apparatus used at both places, it is not necessary to refer to it further.

Some of the fossils obtained by Mr. Colebrooke in the hills near Cooch Behar, and described by Mr. Pentland†, are identical with some of those obtained by the present discovery; and as the former were found in the most eastern extremity of this line, it is possible that a careful examination would prove the existence of animal remains throughout the whole of the intermediate mountains; all the tract being probably tertiary. An inquiry into the difference between the hills bounded by the Ganges and Jumna, and those westward of the latter; and into the confused and interminable dislocations, without any flats in the former, and the more scattered ridges with the intermediate plateaux of the latter, would only lead to a disquisition on the general formation of the dhoons or valleys lying between the Sevâlik hills and the great chain, which the limits of this communication will not admit, and must be left for future inquiry. It will be sufficient to state, that the general form of the mountains approaches more or less to a right angle, the long slope being covered with vegetation, and the crest terminating in a perpendicular and generally mural cliff, which descends into the beds of the torrents. The scenery from these cliffs is most picturesque, and many of the passes or ghâts up the torrents are bounded by gigantic walls of sandstone, varying both in height and character, and subject to all the tortuosities dependent on a river's course, forcing its channel through a complication of mountains. This effect is considerably heightened by the pointed and jagged style

* See further particulars of the gold-washings in the Gúmté river, by Capt. Cautley, Journal Asiatic Society of Bengal, vol. iv. p. 279; Plate VII.; April, 1835.

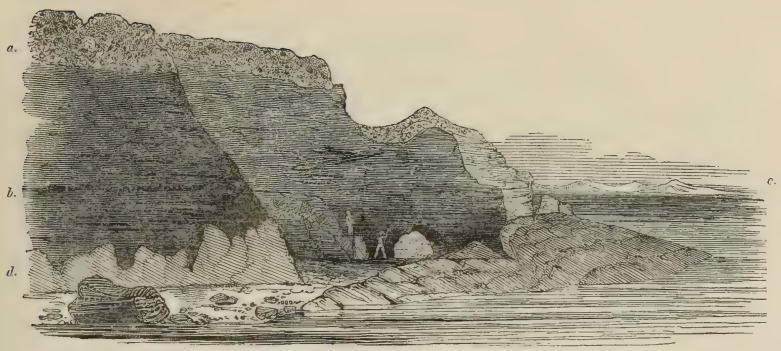
† Geological Transactions, Second Series, vol. iii. p. 393; Pl. XLV.

of the outline, depending on that abundance of clay and carbonate of lime throughout the whole formation, which permits even the shingle-beds to hold up their pointed summits in the wildest manner imaginable. At places, a perfectly inaccessible needle of shingle raises its head far above the others, and is crowned by one solitary fir tree, *Pinus longifolia*. This conical form, produced in the clays by weathering, is sometimes magnificently displayed, by the whole face of a cliff, consisting of light pink, yellow, and blue clays, being externally decorated with small conical spires of the clay from top to bottom, a height of 1000 feet from the bed of the river. The origin of this structure is due simply to a little coping stone, of some harder material than the matrix of the strata, and upon which the weather does not act so rapidly as upon the clay. Under a bright sun, the beauty of these cliffs, with their illumined pinnacles, is exquisite; particularly westward of the Jumna. I have before adverted to the presence of great abundance of lime, forming stalactites, and the cement of the sandstone and conglomerate. There is another striking method of deposition on the surface of the large stones which lie in the beds of the rivers, and which, during the greater part of the year, are in contact with the water. The substance is very similar in appearance to the coarse brown paper made in this country; and is produced by the water, while washing the stone, depositing its lime, and entangling the finer particles of vegetable matter, sand and mica, until the stone acquires a superficial coating, of a brownish yellow colour, which on removal resembles the substance before mentioned.

Manukmow, near Suharunpoor,
June 30, 1835.

Note by the Editor.

For detailed descriptions, by Capt. Cautley, Dr. Falconer, Lieut. Baker, and others, of the most important animals found in the Sevâlic Hills, see Asiatic Researches; Calcutta, 1836; vol. xix. Part. I.; and Journal of the Asiatic Society of Bengal, No. 35. vol. iii. p. 527; Nos. 45, 46, and 48. vol. iv. pp. 495, 565, 706.; Nos. 49, 53, 55, 57, 58, 59, 60. vol. v. pp. 38, 291, 294, 486, 579, 661, 739, 768.



a. Local debris. *b.* Raised beach. *c.* Blown sand-hills. *d.* Silurian rocks.

XXIII.—*Description of a Raised Beach in Barnstaple or Bideford Bay, on the North-West Coast of Devonshire.*

By the Rev. Professor SEDGWICK, V.P.R.S., F.G.S., and RODERICK IMPEY MURCHISON, Esq., F.R.S., F.G.S.

[Read December 14, 1836.]

DURING a recent examination of the county of Devon, undertaken in the hopes of ascertaining the geological succession of the more ancient rocks of which it is composed, we were unexpectedly gratified by the sight of the finest raised beach which has come within our observation. It extends, at intervals, along the shore and cliffs, for a distance of about three miles from the northern side of the mouth of the Taw, or Barnstaple river, to the bold headland called Baggy Point. After toiling through the hillocks of blown sand which encumber the mouth of this estuary, we were turning the rocky headland of Saunton Down, when, to our great surprise, a succession of yellow-coloured, low cliffs broke upon our view, running close along the shore, and rising to a height of about 50 feet, as an undercliff, upon the sides of the ancient rocks which form this part of the coast. It was evident (even at the considerable distance from which we first saw it) that this undercliff was composed of horizontal layers;

and as, in colour and aspect, it differed entirely from any rocks by which we were surrounded, we first imagined it to be an outlying mass of oolite or green sand; nor were we undeceived, until we actually descended to the shore, so precisely did it resemble the sea-worn cliffs of many of our younger secondary formations. We then found that the top of this undercliff was occupied, to a depth of eight or ten feet, by a mixed detritus of angular fragments of the adjacent rocks, contained in a matrix of sandy loam. Beneath this drift, the yellow cliffs, which had attracted our attention, consisted, at their upper part, of finely laminated sand, with here and there an imbedded sea-shell, such as a common cardium or oyster, but generally in too fragile a condition to bear extraction. These beds of sand are about 25 feet thick; and, as they pass downwards, they become harder, and are occasionally interrupted by a course of small water-worn pebbles, perfectly identical with common beach shingles. Though usually arranged in horizontal laminæ, these sands presented, at intervals, those appearances of *false bedding* so common in our tertiary and secondary strata (see vignette), putting on the form of wedges, the laminæ of which run diagonally across the principal layers of the deposit. In descending to the shore, we found the lower part of the cliff passing into solid sandstone, and, finally, into a hard bed of shingle, or conglomerate, resting upon the highly inclined and broken edges of rocks, which we refer to the "Silurian System."

This portion of the cliff, consisting of hard sandstone and associated shingle beds, contains several marine shells, of existing species, among which are *Cardium edule, Patella vulgaris, Mytilus edulis, Solen, Donax trunculus*?.*

On examining this portion (the lowest part being generally about three feet above high-water mark, at spring tides), we were forcibly struck with the analogy which the strata presented to many rocks formed before the present æra. The grains of sands are agglutinated into a compact mass, which, on fracture, exhibits a shining, *chatoyant* lustre, common to calcareous grits of the secondary rocks, with an occasional tendency to run into concretionary forms; and these regularly bedded, stony masses, pass into grit and shingle on the one hand, and into soft, incoherent sand, on the other. The maximum thickness of these lower consolidated strata, at the point where we first met with them, is about 11 feet, of which the upper seven feet are sandstone, and

* We believe that all the shells in this raised beach belong to existing species. We should not, however, have been surprised had it contained some organic spoils resembling those of a warmer climate: for seed vessels of Mimosæ, inhabitants of the Mexican Gulf and the West Indies, are annually washed on these shores, by currents probably connected with the great Gulf stream. We met with several examples of this kind.

the remaining four coarse and hard shingle. Occasionally, however, a small band of fine shingle, or a pebble of considerable size, may be met with in the upper portion.

There is no exaggeration in stating, that much of this modern deposit is quite as difficult to break as the ancient Silurian rock on which it rests. By its texture, it will resist the ordinary action of weather; but the surge, in violent storms, beating against the lower portions of it, has worn them into caverns (see vignette), exposing, in their interior, the edges of the shelly beds; whilst over them is seen the successive beds of sandstone and sand, above noticed. At the point where these appearances are presented in greatest perfection, the total thickness of the beach amounted to about 36 feet; which, with the overlying drift, and the inferior ledge of Silurian rocks, gave a height of 40 or 50 feet. By reference to the vignette, it will be perceived that the bottom of the beach accommodates itself to all the irregularities of the subjacent rock, just as sand and gravel are arranged upon the broken edges of the chalk in the south-eastern parts of England.

The deposit we have been describing, is continuous from Saunton Burrows, where it disappears under the blown sand, to the south end of Croyde Bay, on approaching which the cliff gradually subsides. Throughout the area of that sandy bay, the rocky and high ground recedes from the shore, and there are no traces of the beach for nearly a mile; but on the northern side of the bay it is again met with near some lime kilns, where the lower shingle beds are perhaps fuller of shells than in any other part of their course. Here the coarse shingles, in parts expanded to the thickness of 19 feet, rise rapidly to the north, from a point three or four feet above the sea-level, to a height of 60 or 70 feet above high-water mark, resting on the rugged and abrupt face of Baggy Point—one of the boldest and loftiest headlands on this coast. It is worthy of remark, that it is near the point of greatest elevation, that the materials composing the beach are most coarse and brecciated, and in the greatest quantity.

Such is a brief sketch of the nature and arrangement of this deposit, the position of which naturally leads us to offer a few remarks on the causes by which it has been produced. To this end, we shall endeavour to show, 1st, that the configuration of the neighbouring coast harmonizes with the supposition that this beach has been raised (within the modern æra) from beneath the sea to the height at which we now find it; 2dly, that similar phenomena, on the coasts of Devonshire and Cornwall, and in other parts of England, agree with and confirm this hypothesis.

1. *Phenomena on the Coast and in the Neighbourhood.*

We have stated that the southern end of the raised beach is lost under the blown sand of Saunton. This blown sand occupies a wide area of undulating hillocks (partially covered with bent-grass), which choak the northern side of the bay; the united rivers, Taw and Torridge, finding their course through them to the sea over bars of sand, which render the access to the ports of Bideford and Barnstaple very difficult. On the southern side of the bay these sand-hills disappear; but, between the town of Appledore and the sea-shore, is a very remarkable and elevated straight ledge of rounded bowlders, called the "Popple," or pebble bank; which, although quite analogous to the well-known "Chisel Bank," has not been noticed in the map of the Ordnance Survey. It rises to a height of about five feet above the high-water mark of spring tides, is about one mile and a quarter long, and about 15 to 20 paces wide upon its summit, with shelving slopes on each side, giving it a broad and firm base. It rises from 10 to 12 feet above the sands. The large rolled and rounded blocks, mixed with smaller gravel and pebbles, consist exclusively of a hard, grey and slightly mottled sandstone, of which there is a vast abundance on the reefs and headlands between this spot and Clovelly, and which, with the other strata around Bideford, we consider to belong to rocks of the age of the coal measures.

This pebble bank, stretching from Rocks Nose northward towards the mouth of the estuary, shelters the marsh land behind it from the elements; and hence it is, that a broad and low alluvial flat, interposed between it and the town of Appledore, is covered with grass, and exempted from the destructive sweep of the blown sand, which has overspread the opposite side of the bay. Although it at first seemed difficult to account for the origin of this remarkable ridge of gravel, it appeared to be explained by the raised beach on the northern side of the bay: for we could not avoid inferring, that this pebble bank was one of the indications of a considerable rise of the land. In a former condition of things, when the neighbouring coast was at a lower level, the materials of the present shingle bank might have existed as a natural marine accumulation, in the form of a reef; or they may have gradually assumed their present form, while the sea and land were changing their relative level. Such a change would inevitably bring successive parts of the coast within the destructive operations of the surf, and naturally produce accumulations of water-worn materials. At all events, the "Popple Bank" appears to us not accounted for by the actual configuration of the coast and the ordinary action of the sea.

In addition to what has been said, we may remark, that the interior of the country near Barnstaple, has the configuration which we might expect on our hypothesis: for we may follow, both on the north and south side of the low tract near the mouth of the Taw, ridges of hills extending far into the interior, and having the exact form of an ancient coast-line.

2. *Similar Phenomena on the Coasts of Devonshire and Cornwall.*

Were the appearances above stated without any parallel on the English coast, they would be comparatively of small interest. In fact, however, they form but one of a long series of phenomena, all tending to the same conclusion, viz. the changes of sea level during the modern period. We have no reason to look for frequent examples of raised beaches on the *eastern* shore of England: for, supposing them to have once existed, most of them would have been long since swept away by the encroachments of the sea line. But on the iron-bound coasts of Devonshire and Cornwall, this line is nearly stationary; and, where the forms of the land have favoured the manifestations of changes of sea-level, raised beaches may be traced in so many places, as to form an almost connected series of phenomena. The raised beach of Hope's Nose has already been described by Mr. Austen; and after an examination of the spot, we think his description exact, and his conclusions true*. We there find shingles and shell beds alternating in thin layers, utterly unlike any thing drifted by wind, or placed in their present position by the hand of man, and admitting of no rational explanation, except that which we have given of the similar beach in Barnstaple Bay.

The Rev. Mr. Hennah long since pointed out to one of us, a shingle beach at Plymouth. Similar phenomena were observed by us, in 1828, on both sides of the western extremity of Cornwall: and in the elaborate work of Dr. Boase†, not only are numerous examples cited, of horizontal deposits of shingle and shelly marine sands at various levels above high-water, but the true cause is assigned for some of them—a change of sea level. Unfortunately, however, his descriptions are obscured by language derived from the then prevalent diluvian theory; and on that account do not produce their deserved impression.

The accurate survey of Cornwall, by Mr. de la Beche, cannot fail to give us all the information we want on this interesting subject; and we may expect from him a detailed account of all the phenomena of elevation and depression (for there are proofs of both) exhibited on that coast. We may, how-

* Proc. Geolog. Soc., vol. ii. p. 102.

† Trans. Roy. Geol. Soc. of Cornwall, vol. iv. pp. 259, 270, 273, 320, 466.

ever, state generally, that the Cornish raised beaches, are not all at one level, nor of one character; and though they are all of the modern æra, they do not belong to one epoch of elevation. They may be divided into

1st. *High shingle beaches,* resembling the large rounded blocks so constantly seen at the highest water level on all rocky shores.

2dly. *Mid-water beaches,* composed of rounded pebbles, broken shells, &c. exactly resembling materials washed up between high, and low water mark. These accumulations are seldom regularly bedded, but have more or less of a confused aspect.

3dly. *Low-water beaches.* These have originally extended from a few feet above low water, to an indefinite depth; and, consequently, such masses *are regularly* stratified, being made up of small gravel, alternating with sand, single shells, and beds of shells, all similar to living species of the present coast.

Such appears to us a natural division of these beach deposits; and the Cornish coast offers fine examples of each class.

The phenomena, described by Mr. Carne, near the Land's End* (viz. large rounded blocks, 30 or 40 feet high, in the successive bays and headlands, and nearly all at the same level), were observed by one of the authors in 1828; but, misled by the diluvian theory, he then misinterpreted their meaning. But we can now perfectly understand how these *high-water shingles* should appear by themselves, the other parts of the beach having been washed away. The shingle beach at Plymouth may be mentioned as an example of the second class. But the third class is incomparably the most interesting; because it conducts us to the old water-worn rocks, once washed by the sea, and forming the actual ledge on which these low-water beaches rest; and also because, having been partially deposited under the sea, it is charged with abundance of marine spoils, and sometimes with regular beds of sea-shells. Of course, the shells, as in beaches of the present day, were for the most part dead, when entangled in the layers of sand; but in some cases, we have a proof, that the animals were not dead at the time they were first entangled in the deposit where we find them; though *now* raised many feet above the highest tidal level.

Such examples may be seen north of St. Ives Bay, and south of New Quay, and at several other parts of the north coast of Cornwall†. Now in most cases of raised beaches, we may infer, *à priori,* that the coast was shelving and shallow before their elevation; for such beaches could adhere but imperfectly to an abrupt shore; and if adherent for a short time, would soon be washed away. Hence it is, that where we find raised beaches, we may look for extensive

* Trans. Roy. Geol. Soc. of Cornwall, vol. iii. p. 229, *et seq.* † Ibid., vol. iv. p. 259.

low-water sands. The two sets of phenomena generally occur together, so that one becomes an indication of the other.

On the coast of Cornwall, wherever we meet with low-water sands of any extent, they are drifted by the fierce western gales over all the neighbouring cliffs, and, in course of time, have, in some places, converted whole parishes into deserts. After what has been said, we need not be surprised that these drifted sands should chiefly occur along those parts of the coast, where raised beaches most prevail: in short, the two things are generally found together. This fact misled some of the early writers in the Transactions of the Royal Geological Society of Cornwall*, who attributed the raised beaches themselves to the blown sand, under which they, as well as the older rocks, were partially buried—a very great mistake, though quite natural at the time when it was made. Dr. Boase, we believe, had the merit of first pointing out this error †.

The conclusions from these facts are obvious, and in perfect harmony with our observations on the beach and shingle of Barnstaple Bay; both as respects their structure and their occurrence in the mouth and seaward flanks of an estuary, so much covered by blown sands.

The elevation of the northern side of Barnstaple Bay, makes it almost certain that the south side must also have been affected by a similar movement; and in our reasoning respecting the "Popple-Bank," and the configuration of the neighbouring country, we have assumed that both sides have been raised above a former level, by a similar movement. But, at the time of our rapid passage along the cliffs south of Rocks Nose, we were not aware of the existence of any phenomena on the northern shore of the bay, or, indeed, on any portion of the east coast of Devon, such as we have now described; and hence we omitted to look out for any direct proofs of elevation. Again; the great elevation of the coast line, extending to Baggy Point, could hardly have taken place without simultaneously affecting the portions of North Devon and West Somerset, which form the southern shore of the Bristol Channel. There, however, we found no traces of any raised beaches, though our attention had been previously drawn to them. Their absence is, however, easily accounted for, by the very abrupt form of these bold cliffs, and the deep seas by which they are washed; which are so adverse to the formation, and permanent elevation, of extensive shelly and sandy deposits, like those above described.

The raised beaches to which we have alluded, in South Devon and Cornwall, have been stated to indicate an elevation of the land, varying from 10 to 40 feet; but our case, in Barnstaple Bay, gives a maximum rise of 60 or 70 feet, indicating a greater intensity of elevatory movement as we proceed to the north. If we ascend the estuary of the Severn, and follow that river up

* Trans. Roy. Geol. Society of Cornwall, vol. i. p. 4. † Ibid., vol. iv. p. 260.

to the highest navigable points in Shropshire, we find (as has been shown by one of the authors*) that gravel and sand, with sea-shells of existing species, occur in many places, at elevations of from 300 to 600 feet above the sea: and still further to the north, the elevation of similar deposits is maintained through Lancashire, till they approach the mountains constituting the southern fringe of the Cumbrian chain. Hence we have no hesitation in admitting, that in a portion of our island which ranges from Cornwall and Devon to the southern limits of the Cumbrian chain, there have been great movements of elevation subsequent to the creation of existing mollusca; these movements apparently increasing in intensity as we proceed from south to north, or rather from south-west to north-east.

No doubt there are many portions of the coast of our island, where we not merely have no proofs of any change in the relative level of land and sea, produced by elevation during the modern period, but where we appear to have direct evidence of a partial depression of the land. It is not, however, our intention to enter any further on these subjects. We have described a local phenomenon of some interest, and endeavoured to show its connexion with similar phenomena on a more extended scale. But any consideration of the effects produced by such movements as we have described, on the general configuration of our island, or on the drifted materials which are accumulated on its surface, would lead us into details quite beyond the purpose of this short memoir.

* Proceedings Geol. Soc., vol. ii. p. 333.

Sectional view of the Raised Beach.—*a*, Sand Banks. *b*. Raised Beach. *d*. Silurian Rock.

XXIV.—*Extract from a Letter, by the* Rev. David Williams, F.G.S., *on the raised Beaches in Barnstaple or Bideford Bay.*

[Read March 8th, 1837.]

THE first beach extends from Braunton, or Saunton, Burrows, (where its eastern limit is concealed by ancient drift sand) to Downend Point, round which it winds, and flanks the southern promontory of Croyd Bay. On the north coast of this little bay are vestiges of another beach, extending in patches from near the lime-kiln, to the bold and bluff headland called Baggy Point. In consequence of its prolongation into deeper water, and its having been consequently exposed to a more constant and heavy action of the sea, it is, in places, nearly all removed; but enough remains to show, that it once extended a long way between Croyd Sands and Baggy Point. In both instances the beaches contain abundance of recent marine shells, and afford a sufficiently compact and tough sandstone to be used in the construction of boundary walls. They frequently present the diagonal lines mentioned in the paper of Professor Sedgwick and Mr. Murchison, and so common in the new red sandstone.

That these beaches have been raised from five to ten feet, or that the level of the Atlantic has been depressed to that amount, I have no doubt; for on a careful examination of the slate rocks, at their immediate contact with the present base of the ancient beach, I found, in many places, countless *Balani* on the surface of the slates, yet so entangled and cemented in the sandstone, that, on detaching a mass of the latter, the *Balani* were torn off the slate. It is probable, that they may be also found at higher levels under the sandstone, as at points where I noticed them, the beach had been denudated horizontally at least twenty-five feet. It is certain, however, that they may be seen from five to ten feet above the level, where the living *Balani* exist on the same slate rocks; and there is a considerable interval between the living and the dead, where none occur.

Another fact in corroboration of the relative changes of level, as regards the sea and the sand-cliff, is a magnificent granite block at the base of the sandstone, and resting directly on the slate rock, but above high-water mark. It is so perfectly smooth and close-grained, and so rounded at its edges and

angles, that I had great difficulty in detaching a small fragment. Its exposed surface is six feet long and three feet deep; but I could not ascertain its real dimensions, as its further extremity is concealed by the incumbent sandstone of the beach, and its base by shingle. It is flesh-coloured, like much of the Grampian granite, and is traversed by two veins of red-coloured, compact felspar, intersecting each other. In my opinion it is neither Lundy, Dartmoor, nor Cornish granite.

As the beaches show few or no evidences of disturbance, resting in horizontal unconformity, on highly inclined slate rocks, I inferred that the movement which effected their elevation was gentle, or that a great area had been simultaneously raised *en masse*. With this impression, I examined the district for phenomena, which might corroborate the hypothesis, that the present position of the beach was due to gradual elevation, and not to a depression of the level of the ocean. When we examine the submerged forest extending from the mouth of the Parret to Minehead, can we deny that there must have been a subsidence of this line of coast at a recent geological period? If we continue our researches in the marshes, about seven or eight miles to the eastward, we observe at Benthill and in King's Sedgmoor, sand-banks and ancient sea-beaches, containing an abundance of recent marine shells. Looking at these sand-banks on the one hand, and the submerged forest, containing stags' horns, hazel-nuts and leaves on the other, I apprehend that the phenomena can only be explained by partial elevations and depressions of the land, and not by lowering of the ocean's level. The distance may be fifty miles between the submerged forest and the beaches of Barnstaple and Bideford Bay; but when we consider the great scale on which Nature conducts and has conducted her operations, I trust, I am not straining probability too far, when I assume that the oscillations and vibrations which could elevate the old bank or beach at Santon Downend, and a great adjacent area of land, would extend along the whole coast.

Bleaden, near Cross,
December 31st, 1836.

XXV.—*Memoir to illustrate a Geological Map of Cutch.*

By C. W. GRANT, Esq., Capt. Bombay Engineers.

[Read February 22, 1837.]

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Geographical Position, and Physical Aspect.

THE province of Cutch, in the East Indies, is situated between the 22° and 24° of north latitude, and 68° and 70° of east longitude*. It is bounded to the north by the Grand Runn, beyond which is the Thur or Little Desert; to the S.W. and S. by the Gulf of Cutch and the Indian Ocean; to the E. and S.E. by the district of Guzerat; and to the N.W. by the eastern branch of

* See Map, Plate XX.

the Indus and the territory of Sinde. Its extreme length from E. to W. is about 180 English miles, and its extreme breadth is 50 miles; but in one place it is not more than 15 miles across. It contains about 6500 square miles, independently of the Grand Runn, which ought, however, to be considered as a part of the province, and which, including the islands with the portion bounded by the Guzerat coast, occupies an area of at least 9000 square miles.

Physical Aspect of the Country.—The province is hilly and rocky, with the exception of the part forming the southern coast, which is a dead flat covered with a fine rich soil. Three distinct ranges of hills, having an easterly and westerly direction, may be traced (see Map, Pl. XX.). The most northern forms an irregular chain bordering the Runn, and, for the greater part, presents to the north a perpendicular cliff surmounting a sloping talus, and to the south an inclined plane. It is composed chiefly of rocks, containing marine remains. The next, called the Charwar range, passes transversely through the centre of the province, and is connected with the former, at its north-western extremity, by a cluster of hills. It consists partly of sandstone containing beds of coal, and partly of a series of strata of slate clay, limestone slate, and slaty sandstone. The third, or southern range, and composed entirely of volcanic materials, has the same direction as the other two; but it is of smaller extent, and a branch of it, striking nearly north and south, passes through the centre of the Charwar range. A number of isolated volcanic hills are also scattered over the plain and in other parts of the province, particularly on the borders of the Runn, where is situated the hill called Denodur, the largest in Cutch.

There are no constant streams, the river courses being merely channels for conveying the periodical floods to the sea, and containing, during the remainder of the year, only detached pools. The banks of these courses are, however, very high and precipitous, and afford excellent sections of the strata through which they pass.

Formations.

I have divided the country into the following eight distinct formations:—

1. Syenite and quartz rock.
2. Sandstone and clay, with beds of coal.
3. Red sandstone.—This formation I have not coloured in the Map, having been unable to trace its boundaries. In mineralogical characters it resembles the new red sandstone of England, and differs materially from No. 2., or the formation which contains the coal.
4. Upper secondary formation, consisting of slate clay, limestone slate, and slaty sandstone, and containing *Ammonites*, with other fossils characteristic of the secondary formations of Europe.

5. Nummulitic limestone and marl.
6. Tertiary strata.
7. Alluvial, or recent deposits.
8. Volcanic and trappean rocks, including all such as bear evident marks of a perfectly igneous origin, as basalt, &c.

These eight divisions, considering the red sandstone as one, represent generally the geological structure of the province, though many minor subdivisions might doubtlessly be made; and the surfaces coloured in the Map, must be considered rather as giving a general idea of the extent of the different formations, than as defining correctly the boundaries of each division.

1. Syenite and Quartz Rock.

The only good example of syenite *en masse* is a hill called Calunja, near the town of Nuggur in Parkur, a district in the Thur, and not far from the mouth of the Loonee river. It is not in Cutch Proper; but as it forms part of the northern coast of the Runn, and is in other respects connected with the geology of the province, I have introduced it as one of the formations.

The Calunja hill is a confused heap of light red syenitic rocks, composed of quartz, red or white felspar, and large long crystals of hornblende; the compound being sometimes coarsely grained, and sometimes finely. The base of the main hill is surrounded with small conical mounds, which, at a distance, resemble the huts of a village. On entering the space occupied by these mounds, the hill presents a number of irregular, shattered masses, the sides of which are so steep, and are worn so smooth by the action of the elements, as to be extremely difficult of access. Between these masses the sand lies very deep. It is quite evident, that this hill has been violently acted upon by earthquakes.

In the bed of a river near the village of Koonerea, in the Puchum island, situated in the Grand Runn, I found some masses of precisely similar syenite, which were probably erratic blocks from the Calunja hill; and it will be seen, by referring to the Map, that this island lies nearly in the direction which would be taken by any sudden floods, coming down the Loonee river.

Quartz Rock.—This rock is principally developed in a hill of considerable height near the town of Mhurr, situated towards the western side of the province. The upper part of the hill is entirely composed of it, and huge masses are scattered about the base. A large cleft extends about half way up the western face of the hill, and displays its internal structure, consisting of a

centre of quartz rock, surrounded by horizontal strata of loose, quartzose sandstone. The quartz rock varies considerably in character, being sometimes perfectly compact, exceedingly hard, conchoidal in its fracture, and smooth or foliated on the surface; in other parts it is saccharoidal; occasionally it consists of larger particles, so firmly cemented together that they break with smooth surfaces: some masses, again, have a decidedly granular texture; and one variety is composed of rounded pebbles of quartz of the size of marbles; but in no specimen did I find any other material than pure quartz.

From the extremely fractured appearance of this hill, and from the quantities of basalt lying about, and forming the principal part of some small hills immediately adjoining it, there can be no doubt that it has been subjected to igneous influence; and to the same cause the variety in the texture of the quartz is also probably due, some portions appearing to have been sufficiently fused, for its particles to have agglutinated into a solid mass. This opinion may perhaps be further strengthened by an examination of the country near the town of Mhurr, distant about one mile and a half, where various dykes of basalt traverse the strata. Similar intermixtures of quartz with basalt occur in a hill called Peaka, from its piebald appearance, not far from Joorun, on the Runn, and nearly opposite the south-west extremity of the Bunnee: also in some low hillocks at the base of the Katrore hill in the Charwar range. At the village of Ghuranee, about ten miles east of Mhurr, a large dyke or vein of quartz protrudes from a level plain, and forms a ridge of solid rock about 30 feet in height. Basalt also crops out near the same spot.

2. Sandstone and Clay, with Beds of Coal.

This formation occupies a considerable portion of the country (see Plate XX.), and consists of a regularly stratified series of thick beds of sandstone, alternating with slate-clay, which contains, occasionally, bands of ironstone; and where the coal occurs, it is intermixed with blue clay or shale, and a greasy substance resembling fullers'-earth. South of the Charwar range, the general dip of the strata is S. by W. and S.W., at about one foot in twenty or thirty; but north of that range, the dip varies so much, that it is impossible to ascertain the prevailing direction; and the whole series is so broken, and intersected with dykes and dislocations, as to render fruitless all attempts to determine its general strike.

It will be seen by the Map, that the centre of the province is dotted with hills containing igneous rocks; and the disturbed state of the beds, in their vicinity, may easily be conceived. The smaller hills are composed of con-

fused heaps of a very ferruginous sandstone and ironstone, belonging to this formation, and the surface soil is a deep sand. The texture of the strata varies from a coarse, loose sandstone to a compact and extremely hard quartzose grit and conglomerate, cemented by ferruginous matter, some specimens being almost black.

Iron Ore.—In this formation, the iron ore smelted for commerce is procured. It is found in different parts of the country, but has been principally extracted near the town of Doodye, opposite the S.W. termination of the Bunnee. It there occurs in small lumps, which are of a spongiform texture, small specific gravity, and are very frangible. The natives, however, value this variety more than the heavier, from its yielding with greater ease to their imperfect means of smelting.

Manufacture of Iron.—In extracting the metal, layers of very small pieces are disposed alternately with others of charcoal, in a rude open furnace, and exposed to the blast of two small bellows made of sheep-skins. The metal, when fused, falls into a hole at the bottom of the furnace, whence it is transferred to an inclosed furnace, and subjected to similar blasts, until brought to a white heat, when it is taken out and beaten into a bar. No flux of any kind is used. A considerable quantity of iron was, at one time, made from a totally different description of ore, found near the village of Punundrow, in a plain which extends to the sea or eastern mouth of the Indus. This plain is bounded to the south by low hills covered with fragments of basalt, being outliers of a basaltic range further to the south-east. The surface of the plain is composed of a fine smooth gravel, composed of comminuted particles of iron ore, and has every appearance of having been, at no distant period, covered with water. The iron ore is found near the surface of the low hills above mentioned, in small tabular fragments imbedded in a purple-coloured earth; and those pieces are selected, which give a bright streak on being struck by a pointed instrument. Externally the ore is of a purple colour, and internally presents small dark blue fibres, arranged at right angles to the surface of the specimen. In another place a variety occurs, which resembles small fragments of tile, but has the same internal structure. It is very hard, and of considerable specific gravity; and is said by the natives to have yielded a much greater per centage and much better iron than the ore found at Doodye; but the manufacture of it has been suspended, owing partly to the scarcity of fuel, and partly to English iron being procured at a cheaper rate, as well as in much more convenient forms.

Coal.—Coal has been found in this formation in various places, but not in beds sufficiently thick to be worth working. It was first discovered in the bank of a river near the city of Bhooj, forming a bed about 18 inches thick, and associated with strata of sandstone and blue clay, the dip being, to the eastward, one foot in twenty. This bed was worked for some time, and considerable quantities of its produce were sent to Bombay, but the quality was bad, being very slaty, and containing a large proportion of incombustible matter. Attempts were afterwards made to discover coal in other parts of the province; and although various beds were met with, they were too thin to be of any value. This search was carried on principally to the south of the Charwar range, a few miles from the town and fort of Seesaghud.

One bed was found of a very good quality, but only 9 inches thick. It consisted of masses composed of small cubical pieces, which soiled the fingers very much, had not the slightest appearance of a lignite, and ignited quickly, burning with a bright flame, and leaving a small residuum, but it would not cake. It was found on trial to get up the steam of an engine-boiler very well and quickly, but a much larger quantity was required than of English coal, owing, partly, to its breaking into so small fragments as to fall through the bars of the grate.

Borings for Coal.—A boring for coal was made near this bed; and although 270 feet of sandstone and blue clay were penetrated, no coal was found. A similar attempt was made six miles further to the eastward, and to the depth of 191 feet, but with no better success; and similar researches were made in one or two other places. The second trial passed through a regularly alternating series of sandstone and blue clay. Some of the sandstones were so extremely hard (being composed of quartzose particles cemented by ferruginous matter) as to be almost impenetrable. A jumper, worked by a lever-bar, making eighteen strokes in a minute, penetrated, after eight hours' work only, from 1½ to 2 inches. Other specimens of sandstone varied both in hardness and quality; and at a depth of 190 feet, a bed of white, pure quartzose sand was entered, when water immediately rushed to the surface, and continued to flow in such quantities as to stop the work. The shale was of a very dark blue when first brought up, but it lost the greater part of its colour after exposure to the sun. Iron ore and iron pyrites were found. All the banks of the rivers in the neighbourhood present strata of sandstone and slate-clay, with bands of ironstone, and, in places, thin beds of coal. The general dip is, to the south-west, about one foot in twenty; but the strata are greatly shattered and dislocated by dykes, slips, and hitches.

Vegetable Impressions.—The slate-clay, and, in some cases, the sandstone, contained numerous impressions of ferns and reeds*, occasionally of a large size. One specimen, which was flattened, was four inches in breadth, and the outer surface was carbonised, but the interior was filled with sand: this was generally the case, though other specimens were carbonised throughout, and some were mere impressions. In digging wells within the limits in which they occur, coal was frequently found, but always in thin beds; and some of it ought more properly to be called lignite.

Extent of Coal-field.—The coal-field, if it may so be termed, is bounded to the north by the upper secondary or laminated slate-clay and limestone slate formation; and to the south it is cut off abruptly by a low range of volcanic and trap hills. I could not ascertain whether it had ever been covered by any conformable, stratified deposits. Thin beds of coal have been found in various other parts of the formation. The general structure of this series of strata, the quality of some of the coal, the nature of the sandstone and slate-

* Plate XXI.

clay, the impressions and remains of reeds, ferns, &c., the bands of ironstone, the dislocations by dykes, slips, &c., all bear an analogy to the coal-fields of England; but I am inclined, from the vegetable remains, to consider this deposit an equivalent of the oolitic coal of England, and not of the regular carboniferous system.

Alum Works near Mhurr.

The ground on which Mhurr is built, consists of high, irregular banks of marl of every variety of colour, but in a most confused and shattered state. It is surrounded on three sides by steep hills, forming a kind of amphitheatre; and nothing can be more desolate than its appearance. North of the town is a high table-land, which extends to some hills about one mile and a half distant. It is composed, near their base, of a ferruginous quartzose sandstone, on which the variegated marls rest; the latter being covered, in many places, with a bed of coarse gravelly detritus, six or eight feet thick. Imbedded in this gravel, are some very large masses of basalt, and of a very hard, black stone, composed of grains of quartz cemented by an almost black oxide. They are cut into mill-stones for grinding flour. The whole are evidently boulders from the hills to the northward, which were mentioned in the first part of this memoir, as consisting of quartz and basalt. This plain terminates, to the southward, in a high bank overlooking the town, and intersected in one part by a large dyke of spheroidal basalt, which has apparently so indurated the strata of variegated marl in its vicinity, as to permit them to be quarried for building. A large quantity of alum is made at this place, and exported to different parts of India.

Manufacture.—The shale from which alum is obtained, forms beds in the variegated marl; and in a kind of blue clay. Long galleries are cut for the purpose of extracting it; but so plentiful is the supply, that no means are taken to support them, and they generally fall in during the rainy season. The manner in which the alum is prepared is very simple. The earth is exposed in heaps to the sun and air for about five months, during which it burns spontaneously. It is next laid out in little beds similar to those of a field prepared for irrigation, and it is watered by a small stream for ten or fifteen days, by which time the aluminous matter accumulates into semi-crystalline plates. This substance is boiled in water for about seven hours; after which, a third, or one half, by weight, of potash is added, and it is again boiled for a few hours, according to the strength of the ley. It is then poured into large open vessels, where, after settling for some time, it is washed, and the liquid drawn off, leaving an impure crystalline sediment. This is once more boiled, and when it arrives at a proper state, which is learned by practice, it is poured into large earthen vessels with a small mouth, and sunk into the ground to prevent their breaking. After a time, the vessels are dug out, broken to pieces, and a lump of pure alum extracted. Six or eight measures, by weight, of alum, are produced from ten measures of the substance from

the irrigating beds, and four or five measures of potash. It is not so much esteemed in the Bombay market as that brought from China, on account of its yellow tinge.

Some of the marls resemble chalk, being white, and soiling the fingers; and some are very calcareous, whilst other varieties scarcely effervesce with diluted muriatic acid. In one mass I found a very minute specimen of *Buccinum pumilum* (sp. n. Pl. XXIII. fig. 1.). These marls also occur of every variety of colour as well as texture; some of them consisting of innumerable thin laminæ curiously twisted and arranged in the most intricate manner; and others of a kind of breccia, composed of small broken portions of marls. Several dykes of basalt cut through these beds; the whole presenting a most confused assemblage, partly due to natural causes, and partly to the numerous mines which have fallen in. One of the banks has been burning spontaneously for several years, in a similar manner to that at Ruttrea, and apparently from the same cause. The exact geological position of these marls I could not determine.

3. Red Sandstone.

I have mentioned a red sandstone formation, which may be described now. It occurs to the southward of the coal series, and is separated from it by a low range of hills about six miles broad, composed partly of basaltic rocks, and partly of a variety of porphyry. This sandstone is regularly stratified, and has the same dip and inclination as the sandstone and coal series, but differs very materially from it, in being much softer, generally finer-grained, of a vast variety of colours, and by containing no organic remains. Associated with the sandstone are beds of clay, varying in colour from purple to deep red. One of the beds is aluminous, and has been burning spontaneously for a long period. The smoke issues from a deep crevice in the bank, and the fumes are highly sulphureous. A stick thrust into the crevice soon ignites, and the whole bank has a burnt appearance; the red clay, which rests immediately upon the stratum, having been converted into a perfect brick, and the other variegated clays having been variously acted on. Although this bed would yield a large per centage of sulphate of alumina, it has never been worked. The strata dip at an acute angle to the south, and are covered, in that direction, by beds of gravel, succeeded by others of sand and soil, which extend to the sea.

4. Laminated Series or Upper Secondary Formation.

Alternating strata of slate-clay, limestone-slate, and occasionally slaty sandstone, constitute this formation. The more calcareous beds are very hard and compact, whilst some of the others are very earthy and friable. In many of the calcareous slabs, the upper and under surfaces are argillaceous, hard, and compact, but the centre is a grey limestone, which takes a good polish, and might be used for lithography. The slate-clay is of a dark blue colour, and generally peels in thin flakes, leaving a flat, lenticular nodule or centre. In many places, vast thicknesses of this laminated slate-clay occur without the

least admixture of the sandstone-slate, whilst in others, the latter alternates very often with it.

The beds being horizontal, except where they have been disturbed, the formation occupies considerable tracts; and where it rises into hills it is generally capped by a thick bed either of coarse, soft sandstone, as in the ghàts of the Charwar range, the Bhooda hill (near Bhooj), the Jarra (near the Indus), and other hills; or of a very compact, hard, crystalline sandstone, with a conchoidal fracture, as in the Chuppal hills, the Jarra, and in other places, including the natural walls of the Runn, described in a subsequent part.

Relative Position with respect to the other Strata.—I searched diligently to find the relative position of this formation distinctly defined, but in vain, as, at its apparent junction with other beds, the whole of the strata were broken up, and so confused as to baffle every attempt to ascertain the boundary. I am induced, however, to believe that it occupies hollows in the sandstone and coal formation, or abuts against it. It cannot underlie that series, because its strata are always *horizontal*, except where locally disturbed; while the beds of sandstone and coal are as invariably inclined at a considerable angle, and are everywhere intersected with dykes, slips, and other dislocations, from which the upper secondary strata are generally free. In one instance the formation evidently occupied a hollow in the coal sandstone.

In many places it appears to abut against the sandstone, occupying large tracts which may, at some period, have been covered by beds of that formation, subsequently washed away. From what has been stated above, it is at all events newer than the coal beds; and this conclusion is also borne out by its imbedded fossils.

Apparent Position with respect to the English Series.—In its mineralogical character and general appearance, this formation greatly resembles the English lias; but its fossils have been found, after a careful examination by Mr. James Sowerby, to assimilate very closely to those of the oolitic beds; and a very few belonging to the green sand.

Fossils.—Of the fossils found in these beds, the Ammonites are the most characteristic, occurring in vast quantities, particularly in some hills bordering the Runn. Of the eleven species which I collected, eight are unknown to Mr. James Sowerby, to whom I am entirely indebted for all my information regarding them. (See Plates XXI., XXII., and XXIII.) Of the other three species, one so closely agrees with *A. Herveyii* (Plate XXIII. fig. 5.) of the English cornbrash, that he is induced to consider it only a variety of that species; another in the outer whorl (Plate XXIII. fig. 13.) resembles *A. perarmatus* of the coral rag, but differs in the structure of the inner whorls; and the third, of which there is only one imperfect specimen (Plate XXIII. fig. 12.), is like *A. corrugatus* of the inferior oolite of England. They generally vary in diameter, from three to

five inches: the largest I found being eight inches. It was imbedded in a mass of gold-coloured oolite. The genus next abundant is the Terebratula. Of the seven species collected by me, five bear so close an analogy to the *T. biplicata, T. dimidiata, T. sella, T. intermedia,* and *T. concinna* of the green sand and oolitic series, that it has been found impossible to consider them distinct species. The Trigonias are numerous, though confined to two species, one of which differs so very little from *T. costata* of the lower oolites of England, that Mr. Sowerby considers it only a variety of that fossil. The genus *Pholadomya* also abounds, but the specimens are generally broken. Of the three species I collected, Mr. Sowerby has not been able to establish an identity with any known Pholadomya in England, although there is a general resemblance to the oolitic and lias fossils. I found two species of Belemnites, one of which resembles *B. canaliculatus* of the inferior oolite; the other is not determinable. Of the species of oysters, one resembles the *Ostrea Marshii* (see Plate XXII. fig. 9.) of the English cornbrash. I found it in a bank high up the Katrore hill, in the Charwar range, in friable, laminated strata of slate-clay and sandstone slate, associated with Ammonites of the same description as those at Charee and along the Runn*. I did not find a single specimen of a Gryphæa, although numbers of the genus have been collected from this province. Some crinoidal stems, which I collected from the same localities (see Plate XXIII. figs. 14, 15, 16.) resemble those of a species found in the mountain limestone; but as the fossils above enumerated characterize the middle series of the English upper secondary rocks, fossils belonging to so much older a formation can hardly be associated with them. These crinoidal remains, therefore, probably belong to an undescribed species. The only fossil bone which I discovered, Messrs. Clift and Owen consider to be a caudal vertebra of a Saurian. This determination is, however, very interesting, as it shows how widely these animals were distributed; being, in this distant country, also associated with the same mollusca (one valve of a *Trigonia costata* is imbedded in the mass containing the bone) as accompany their remains in the English strata.

In the Appendix to this paper I have given a complete and systematic list of all these fossils, stating the localities where I collected them.

General Shape of the Hills belonging to this Formation.—Many of the hills in Cutch present, on the north side, a perpendicular cliff surmounting a sloping talus, and on the south an inclined plane; and they owe this peculiar outline to their being composed of a base of laminated clay or sandstone, capped by a thick bed of coarse and brittle sandstone. This is particularly the case in the Jarra hill, and the hills of Hubbye, Lodye, and Roha-ké-Koss, near the village of Joorun, on the Runn; also those of the Puchum and Khureer islands in the Runn, particularly the latter; likewise those near Beyla, at the north-eastern extremity of the province, and many others. The Katrore hill, forming the eastern extremity of the Charwar range, belongs to this formation, and, therefore, differs materially from the greater part of the range, which is composed

* At the base of these hills, and forming the immediate borders of the Runn, fossil shells are found of a very different description, among which I may enumerate *Cardium, Pecten, Corbula, Venus, Globulus,* and vast quantities of *Turritella*; which last form large masses of rock protruding every here and there above the bed of the Runn.

principally of sandstone, except in the portion opposite Bhooj, where this laminated series also occurs. The strata being principally horizontal, the hills have a conical form.

It is a curious circumstance, that, in the same group, some of the hills of the laminated strata have a thick capping of sandstone, whilst an immediately adjoining peak, of equal height, has none. I conceive the thick beds of the sandstone once covered the whole surface, and that on their upheavement they broke into masses, which have been since denuded from some of the hills, the debris forming the deep sandy plain around Bhooj.

In the hill of Jogé-ki-bit, near Nurra, on the Runn, the beds dip from 40° to 50° to the north, and alternate three times with basalt. The strata vary greatly in character, some of them being very hard and crystalline, particularly those containing calcareous matter; whilst other parts of the series, immediately adjoining, are very friable and earthy. Some of the schists assume the character of a roofing-slate, and others are only soft, laminated blue clay.

A cluster of hills, occupying a surface of three or four square miles to the north-west of the city of Bhooj, called the Bhoodha hills, also belongs to this formation, being composed of slate-clay, tabular sandstone, and limestone slate, in many parts assuming a very friable, earthy texture, and frequently capped with thick beds of coarse, soft sandstone. The strata are often horizontal; in which case the hills are conical; but in many instances the beds incline at a considerable angle; and the hills assume, when capped by the sandstone, the usual form of an abrupt escarpment, with a long inclined opposite side. They are intersected by numerous ravines and nullahs; the looseness of the soil, and peculiar tabular construction of the strata, offering a very slight resistance to the action of the rains. The Chuppal hills, between Guranee and Nurra, in the north-western division of the province, afford another example of the elevation of these strata into hills. They consist of beds of a very earthy and friable description, covered by a thick stratum of hard crystalline sandstone, slightly calcareous; and the lower part forming a sloping talus, capped by the hard rock, in masses 20 feet thick; they appear as if they were surmounted by old ruins or turrets.

Manner in which the Hills have been formed.—From an attentive examination of these hills, I am led to infer, that they have all been uplifted by a movement which proceeded from below; the laminated series having yielded to the upheaving power, and the loose brittle sandstone having broken off abruptly. That this has been the case with the minor ridges, and what I may

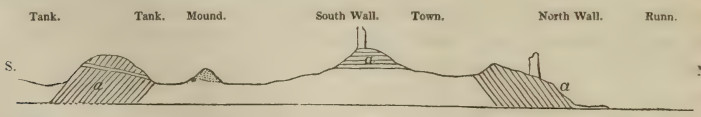
term the *natural walls* in the Runn, described in treating upon that district, there can be no doubt, as I have found them at angles, varying from a few degrees above the horizontal position to the vertical, and even turned over beyond that point.

That these beds have been disturbed and broken through by igneous agents is quite evident from the dykes of basalt, which occasionally intersect them.

5. Nummulitic Limestone and Marl.

Although the imbedded fossils of the Nummulitic group resemble those of some tertiary beds of England and France, still the strata of which it consists, differ so totally in mineralogical character and general appearance from any of the other formations in Cutch, that it deserves a separate notice. It is bounded partly by the second or sandstone and coal formation, partly by beds which I have coloured as tertiary, and partly by the alluvial banks of the eastern branch of the Indus, extending from Luckput to a plain between the villages of Wagé-ké-Pudda and Eyeraio, about thirty miles to the southward. It consists of a mass of small Nummulites mixed with Fasciolites; and some of the river banks present a perpendicular section of solid rock, from 60 to 70 feet in height, entirely composed of these small fossils agglutinated together, and varied only by a species of Orbitolites, frequently bent into a saddle shape. This stone has much the appearance of chalk, and the beds are horizontal, except where they have been disturbed. In some parts, however, it is much harder, particularly near the town of Luckput, where it is quarried as a building stone, and is also burnt for lime. The surface-soil is entirely composed of the small fossils lying loose, and generally known by the name of Luckput sixpences.

The beds of nummulitic limestone on which Luckput stands have been affected in a manner deserving of notice.



The high ground to the east of the town sends off three parallel ridges to the westward, ranging nearly east and west. On the two northernmost of these ridges, the north and south walls of the fort of Luckput are built; whilst the southernmost lies at a distance of about 200 yards from the south wall. A kind of valley runs through the town, ending, at its western side, in a

swamp, which is crossed by the western wall of the fort. A cut through the northern ridge exposes a very good section of the nummulitic stone, dipping 40° to the north; whilst, in a similar cut through the southern ridge, made for the purpose of connecting two tanks, the same beds dip from 40° to 50° due south. In the centre ridge the section is not quite so perfect, but the beds are nearly, if not truly, horizontal, forming an anticlinal axis to the other two.

This elevated tract of the nummulitic limestone extends only three miles to the eastward of Luckput, the ground there descending abruptly into a plain, composed of various clays, a coarse ferruginous stone and sandstone, with quantities of selenite scattered about, the whole presenting a confused appearance, as if it had been the site of an igneous outburst. Patches of ground, every here and there, have also an altered appearance, and are covered with small fragments of igneous rock. The plain is bounded to the south by a low range of basaltic hills. From Luckput southward to the village of Punundrow, the same nummulitic rock continues, but varies in hardness from a compact limestone to a white marl. It is also very well exposed between the villages of Eyeraio and Wagé-ké-Pudda, at the southern limits of the formation. To the S.W. of Eyeraio is a plain, composed of a white calcareous marl, and flanked to the south by a low range of hills of the same material, sending off into the plain numerous small projections, with rounded terminations precisely like headlands. Numerous isolated hillocks, or high banks, with sides worn in the same way, and resembling islands, are scattered about the plain, and the whole surface looks as if it had only lately been deserted by water, or as if a violent flood had swept over it. The banks of the small nullahs, which intersect the plain, are composed of gravel, containing rounded masses of a variety of the calcareous marl. Advancing westward, the ground rises a little, and the surface consists of a hard rock, which contains oysters and other bivalves, whilst in some places large patches are entirely composed of silicified corals. I also found in this place fragments of fossil bone, said by Messrs. Clift and Owen to be parts of rib-bones, like those of the *Manatus*, but flatter. To the north, this plain is bounded by a river, the perpendicular banks of which, 60 or 70 feet in height, consist entirely of nummulitic marl, capped by a thin stratum of gravel. In one part, the bed of the river is subjected to the action of a small stream of water, so strongly impregnated with saline ingredients, that large lumps of salt are formed in the hollows worn in the rock, which here assumes the character of a hard limestone, probably in part due to the quality of the water that passes over it. The beds are horizontal, except where they have been disturbed and shattered.

Characteristic Fossils.—The most characteristic fossils of this formation, next to the Nummulites and Fasciolites, are Echini, Galerites, Clypeasters, and Spatangi. The species of Echini and Galerites are all new. A Clypeaster resembles *C. affinis* of the sandy marl of Brabant; and a Spatangus, the *S. Bucklandii* of the marly chalk of Westphalia; while another species agrees with the *Spatangus acuminatus* of the tertiary deposits of Dusseldorf. The other fossils consist of species of Tellina, Astarte, Cardium, Arca, Pectunculus, Pecten, Nucula, Ostrea, Cerithium, Turbinellus, Globulus, and Seraphe. (See Plate XXIV.) The Turbinella abounds and is often very large. In the bed of the river above described, I found large blocks composed entirely of small oysters, similar to *Ostrea Flabellulum*, but more regularly and finely striated.

6. TERTIARY STRATA.

I have called all that portion of the province *tertiary* which is composed of rocks containing fossils belonging to this period. It consists principally of a hard argillaceous grit, interspersed with fossil shells, and covered by beds of pebbles or conglomerate. Some portions of this conglomerate are very coarse, and constituted of rolled or boulder stones loosely connected; whilst other portions are sufficiently indurated to be used as a building stone. A calcareous grit, which soils the fingers like chalk, also occurs in patches, and contains innumerable small shells. It is used for building, and is burnt for lime. The beds are horizontal, and the surface of the country is generally covered with a fine rich soil.

At the village of Soomrow, about ten miles north-east of the fort and harbour of Juckow, on the south-western coast, (see Map,) the banks of a broad river-bed are composed partly of a loose gravelly soil, and partly of a very hard, compact, calcareous rock, full of shells, and burnt for lime; and below this rock is a coralline limestone. The river-bed, in some places, is nearly a mile across, the banks being cut into ledges or steps, whilst numerous small hillocks, or high banks of gravel and clay, stand isolated in its middle. Only a small stream now winds from shore to shore. One part of the northern bank rises into a small hill, the surface of which is composed of the same hard, compact, shelly rock as that which is found even with the bed of the river. For some distance north of this spot, the ground is also high, and cut into innumerable ravines; and there are breaks in the surface, as well as circular hollows, or large, deep pits. The natives have a tradition, that an earthquake occurred at this spot, some centuries since, during a severe battle between the Sindians and the natives of Cutch. The raised position of the shelly rock, and the peculiarly rent and broken appearance of the ground, indicate some convulsive movement; and it should be noticed, that, as all the beds are horizontal, those forming the hill cannot be an unbroken continuation of those in the banks of the river.

This formation continues a few miles further to the northward, where it abuts against the nummulitic beds.

In many places towards its northern limits, it rises into hills, and considerable tracts of high, undulating country; the loftier portions consisting invariably of hard, shelly rock, including large patches, of one or two acres in extent, of silicified corals; and the lower parts, or intervening spaces, of a loose gravel or clay, equally full of organic remains. Some parts of this district, particularly that near the village of Kotra, have a very remarkable appearance, as if they had been subjected to a violent flood, which had washed away the surface-soil to a depth of 30 or 40 feet, leaving a broad, shallow valley, two or three miles across, with numerous isolated and rounded bluff hills of gravel, scattered about its bed. The banks, or bounding lines, consist of low hills, cut into innumerable small ravines; the whole being composed of the same shelly rock, and gravel, and clay as above described.

The fossil shells found in this district occur often in beds, consisting of a single species. One of the hillocks, above described, is about 60 yards long by 20 broad, and 15 feet in height, and is entirely covered with *Ostrea callifera*, lying loosely on a gravelly soil, or cemented into a solid rock. The highest part of the table-land in one place, near the village of Kotra, is also composed solely of oysters, forming a very hard rock or limestone; other isolated banks are completely covered with what appears to be a species of large Serpula, or else fragments of coral. Numerous other fossils are found, either lying loose or imbedded in the rock, and consist of species of Lucina, Venus, Cardium, Pecten, Ostrea, Turritella, and Clypeaster. The Turritellæ are imperfect, but particularly numerous.

This flat valley or broad river-bed (for a small stream still winds through it,) continues to the hills surrounding the town of Mhurr, spreading, in places, into lake-basins, all of the same description as above detailed; but, a short distance south of the Mhurr hills, its course is cut across by a dyke of very compact basalt, of perfectly columnar structure; each face of the polygons being about two feet in breadth. This basalt forms both banks of the river for 50 or 60 yards, and to the height of 20 or 25 feet; the bed of the river being also formed of sections of the columns. The clay through which the basalt passes is hard, and of a brick red; and quantities of iron ore, of a spongiform texture, are scattered about.

The southern base of the Mhurr hills is now approached, and presents a most confused appearance, the country at their foot being shattered in all directions. It is impossible to conceive ground in a more disturbed state. The

banks and ridges, varying from 20 to 60 feet in height, are partly composed of coarse, calcareous grit, full of the marine shells already enumerated, and partly of a blood-red coloured clay, which has apparently been altered by a trap dyke. One bank exposes a section, 60 to 70 feet high, of horizontal layers of gravel, clay, shelly rock, and iron clay, which in one spot appear to have fallen in bodily, dipping abruptly from both sides to a point.

Fossils.—The principal deposit of fossil shells which came under my inspection, was at the village of Soomrow, just described. The specimens which I collected have been examined by Mr. James Sowerby, and found to consist of 33 known genera. Of the 57 species belonging to these genera, 47 are new, 6 are known, and 4 are doubtful. (Pl. XXV. and XXVI.) The most numerous among the univalves belong to the genera Mitra and Voluta: there are also great quantities of the genera Cerithium and Terebra; some of the latter being very beautifully marked The genera Solarium, Conus, and Strombus also abound. Among the bivalves, the Pectens are most numerous; and among the Radiata are great numbers of Clypeaster. Most of the fossils which I collected, either lay loosely on the gravelly bank, or were cemented into large tabular slabs of rock.

I was informed by the natives, that, about the year 1834, great quantities of large fossil shells, called by the country people *Sonk* or *Conk*, being a species of Turbinella, were found in a land-crack, in a field about two miles from this spot; and so perfect, that they were given to the priests of the different temples in the neighbourhood, who, by inserting a metal tube into the apex of the shell, converted them into horns, to call the devout to prayer. I could not, however, find any when I visited the spot, the crack having been filled up by subsequent floods.

Extent of the Tertiary Formation.—These tertiary beds reach, in one place, to the town of Mhurr, a distance of thirty miles from the sea, and extend in a belt of, perhaps, a third of that breadth, throughout the whole southern coast of the province. A narrow line should also be drawn along the borders of the Runn, and around the islands in it, as the fossils, found on the immediate shores, belong to the tertiary period.

7. Alluvial, or Recent Deposits.

The part coloured as alluvial in the Map (see Pl. XX.) consists entirely of plains covered with soil, evidently detritus which has been washed from the hills, or of land recovered from the sea by the blowing up of sand. The whole of the province south of the volcanic range (see Map) might be considered alluvial; the surface being composed of a thick soil, formed by the rapid decomposition of the basaltic or igneous hills; but as the banks of the rivers contain tertiary shells, I have thought it better to colour the district as consisting of rocks of that age. The boundary between the tertiary and

alluvial districts must, therefore, be considered partly imaginary, as I have thought it more correct to give a general outline, than to mark, with apparent minuteness, limits, which my examination of the district, did not enable me to ascertain.

Land gaining on the Sea.—In many places along the coast, where there are ridges of sand, the land gains upon the sea. These dunes are constantly increasing, from the particles blown up by the sea-breezes, or the south-west winds, which prevail during so great a portion of the year; and the ridges frequently occur in double rows, occupying a considerable breadth, and varying from 50 to 100 feet in height. During strong winds the whole appear to be in motion, from the sand drifting along their surfaces.

At Mandavee, the principal seaport in Cutch, is a ruin on a spot called the Old Bunder, or Quay. It is now about three miles inland, and is situated on the bank of the river, which flows into the sea near the present town; but at the time when this old quay was in use, the town must have been some distance from the present shore. A small temple, built upon a rock, now in the middle of the town, is said to have been at that time also in the sea. Even now, a considerable space, composed of loose sand and sand-hills, intervenes between the town and the sea; and the distance is continually increasing, owing to the quantity of sandy detritus brought down by the river during the periodical floods, and washed back by the sea in the dry season. A bar is also thus formed across the mouth of the river, and the position of it varies so much, and so often, as to render the entrance to the river very difficult. Even boatmen belonging to the port, who have been absent a few months, cannot pilot their vessels in. During very dry seasons, this bar increases to so great a degree as almost to block up the entrance entirely; and the laden boats always strand upon it at high water, their cargoes being carried away by carts, when the tide is out.

At Moondrah, Budraseer, and other seaports up the Gulf of Cutch (see Map), the land also gains upon the sea, rendering necessary the frequent removal, further seaward, of the quays or landing-places. Where rivers enter the gulf, this increase of land at their mouths is easily understood, as the sea, for nine months of the year, washes back the sandy detritus accumulated by the river at its delta during the periodical floods. Where rivers flow all the year round, they may be enabled to keep a channel through the deltas constantly free; but when the stream is inert during three fourths of the year, and the wind and sea are continually at work, the case must be very different.

Marine Forests.—The same operation is in progress at places separated from the main waters of the gulf by small creeks.

Some of these inlets penetrate six or seven miles from the coast through a tract covered for miles in extent with shrubs. At low water, these plants are exposed to their roots; but at high tides merely their upper branches are visible, so that the boats sail through a marine forest, the sails and yards frequently brushing against the boughs of the trees. The growth of these shrubs is so rapid, that the sailors have very often to force their boats through the upper branches, particularly at the various angles of the very tortuous creeks, when they wish to save a tack, and the wind is scant. The stems and branches of the trees are covered with Crustacea

and Mollusca, whilst numerous water-fowl occupy the higher branches; the whole presenting a most curious picture. That the land should gain on the sea, in these places also, is very natural, as during the monsoons, when the numerous small streams convey their muddy alluvium into the gulf, the roots and stems of the shrubs act as a filter, and the water passing slowly between them, a great portion of the earthy matter is precipitated; a portion also adhering to the stems.

Effects of Floods.—Considerable damage is frequently done by the periodical floods, which, from the peculiar hilly structure of the country, sometimes rush down with a force, that carries all things before them.

In August 1834, the rains were very violent and long-continued, and did considerable damage. The river, which flows past Nurra, and through the flat, from six to eight miles broad, which extends from the town to the Runn, brought down so much alluvium, as to cover with a fine soil a surface of 150 pragas, or nearly 1000 acres of land. This tract had been sunk by the earthquake of 1819 so nearly to a level with the Runn, as to have remained unfit for cultivation. On the opposite side of the province, at a village called Kundagra, not far from Mandavee, 50 pragas or 300 acres of soil were entirely washed away, leaving a bare sandy surface, similar to the bed of a river; and not far from the same spot, half a small village, with a quantity of land, was swept bodily into the sea; large trees being uprooted and carried down by the flood. At Pheraudee, 12 miles N.E. from Mandavee, at Mandavee, and many other places, great devastations are said to have been produced. A few similar inundations would alter the features of the country, consisting of such abrupt hills and loose surface-soil.

8. Volcanic and Trappean Rocks.

The district coloured in the Map as composed of volcanic and trappean rocks (see Map, Pl. XX.) is one of the principal features in the geology of Cutch, not only from the space it occupies, but from the phænomena which it presents.

The igneous origin of trap being acknowledged, I shall always speak of it and lava under the comprehensive term of igneous rocks, as in composition they differ only in the proportions of hornblende, felspar, and augite, and as they all appear to have originated in the same cause, and to have equally disturbed or affected the neighbouring strata. But there appears to be a very marked distinction between those rocks which have been in fusion below the surface, and subsequently forced up, and those sedimentary formations, which have an altered appearance, and have been evidently subjected to violent heat since they were deposited in their present position. The latter rocks, however, bear a very small proportion to the former. The part coloured as volcanic shows the principal theatre of the outbursts; but to mark on the Map every spot where traces of igneous action are observable, it would be necessary to dot over the whole of the secondary formations.

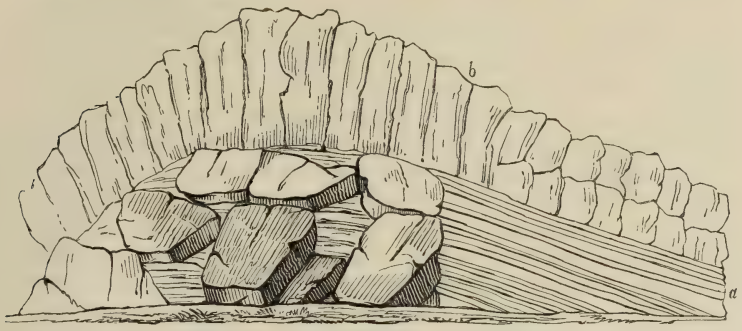
Evidence of the disturbing power of Igneous Agents.—It is impossible to desire clearer evidence of the disturbing power of igneous agents than is developed in Cutch. The shattered appearance of the country in some places, the upraised hills in others, with the igneous rock or moving agent, either directly under them, or immediately in front of the outcrop of their strata; the angles to which the beds have been raised varying from a gentle, unfractured slope to the most complete dislocations; the vast variety in the composition of the igneous matter, from the most loose and clay-like form to the most compact and perfect columnar basalt; the crater-like shape and construction of some of the hills, from which large lava or basaltic streams can be traced, prove the igneous origin of these rocks, and the vast effects which they have produced on the general appearance of the country. Moreover, it is not necessary that the igneous matter should be on every occasion apparent; as, where we find a large mass of basalt which has evidently come from below, lying on a plain, behind a hill presenting a bluff cliff towards the igneous rocks, and the strata sloping sharply from them, the conclusion is obvious, that the hill must have been raised by the outburst of the volcanic matter; and it is equally just to infer, that, in its passage from below, it must have disturbed, more or less, the various beds through which it passed; and, therefore, that the form of many hills may be owing to a latent exercise of this power, even where no traces of the igneous matter are visible near the surface, or near the raised strata. That the greater number of these igneous rocks have been forced up, and are not portions of lava streams which have flowed from volcanos, is very evident, from the manner in which the superimposed strata are affected by them.

In a preceding part of the paper I have described a hill of quartz rock near Mhurr, and shown that its strata have been violently disturbed; and I have also inferred, from the nature of the rock, that its characters are due to grains of sand having been agglutinated by volcanic heat. In detailing the phænomena presented by the second formation, I have shown that its strata have been also subject to great dislocations.

The following wood-cut presents an example of a large dyke of basalt which has cut through the strata in the river near Jaumtra, and thrown them off in opposite directions.

In describing the upper secondary formation, I have stated, that I conceive the hills owe their outline, presenting to the north an abrupt escarpment resting on a slope, and to the south an inclined plane, to the agency of volcanic forces. In the Karee river, near Bhooj, these beds have been disturbed to an extent which defies representation. Near the village of Jarra, on the borders of the Runn, a bank affords a good example of the manner in which this upheaving power has acted. The laminated beds (upper secondary formation) being of a loose earthy character have yielded to the disturbing agent; whilst the overlying compact stone has broken short off, and pre-

sents a wall of rock, split by such perfectly vertical lines, that at first sight I thought the stone was columnar.



Bank near Jarra:—*a.* laminated series; *b.* compact sandstone.

The range of Roha-ké-Koss, composed of beds of the fourth or upper secondary formation, is a good example of disturbing action. It is situated between the villages of Joorun and Lodye, on the borders of the Runn, and extends nearly east and west for eight miles, presenting, to the north, a perpendicular cliff of sandstone, which rests on a sloping talus of laminated sandstone and slate-clay, and dipping at a high angle to the southward. About three quarters of a mile from this main range, and parallel to it, is a ridge of smaller hills, consisting principally of basalt, intermixed, in some places, with the same sandstone as that of the main hill; and which, in the banks of the nullahs at its base, overlies the laminated strata. The space between the two ridges is composed of large broken masses of sandstone, covered by a thick bed of gravel, evidently the detritus of the hills. In this instance, the strata of the Koss range dip towards the south; and, at a short distance to the north of it, we find a mass of basaltic or igneous matter, which probably raised the hills in its passage up, and established itself at their foot. Large basaltic dykes, disturbing the strata through which they pass, are observable in many of the river banks in the immediate neighbourhood.

The beds of nummulitic limestone, on which Luckput stands, present, as before stated (p. 300), most decided marks of elevatory movements, consisting of a central platform of horizontal strata, with inclined beds on the flanks.

Another most striking example of the effects of igneous action in upraising hills, occurs in the nummulitic limestone, near the village of Punundrow; and

the phænomena are so strongly marked, that they deserve a detailed description.

On leaving the village of Korah, in the north-west department of the province, and proceeding westward, a range of hills is entered, of small altitude, but covering a considerable area. It is composed of a confused assemblage of basaltic cones in broken columns, or rather of a number of sugar-loaf-shaped masses piled one on the other. The surface of the hills is covered with fragments of a hard greenstone, the crystals of felspar being numerous. The perpendicular banks of the nullahs and ravines which intersect this range, present, in some places, entire sections of the columnar basalt; whilst others consist of a friable, sandy clay, disposed in horizontal, thinly laminated strata of every shade of black, red, and yellow, to white; and associated with it is a beautiful purple loam. The basalt sometimes overlies these beds, sometimes forms dykes in them; and one side of the ravine frequently consists of this variegated loam, and the opposite of basaltic pillars. In many places the ground has an altered appearance; the ironstone, of which large quantities are lying about, appearing partially fused, and the clays or variegated marls variously acted on, and always accompanied by dykes of basalt. These hills continue about eight miles from Korah to the village of Ukri, where they gradually decline into a plain, throwing off numerous ridges or forks. About three miles distant, a solitary hill, with a flat but uneven top, called Baboa, rises out of the plain. To this hill I wish to draw particular attention; and the foregoing account of the basaltic range has been given as necessary to a proper understanding of it.

The first part of this plain is composed of thick beds of gravel, but further westward it consists of the nummulitic formation. Out of this soil rises the Baboa hill, composed of hard limestone, full of marine remains. One of the forks projecting from the basaltic range reaches to within half a mile of the hill, the ground near it being strewed with small fragments of igneous rock.

The cause of the elevation of this hill is, in my opinion, distinctly visible in the banks of a river which passes by its western base. They are from 20 to 30 feet in height, and are composed of white calcareous marl, covered by a thin bed of gravel. Immediately opposite the hill, these beds are cut through by a dyke of very compact dark green basalt, forming, towards the river, a wall about eight feet high; its base being hid by a talus of gravel. In several places on each side of this dyke, which is about 50 yards in breadth, independent masses of igneous rock break through the marl. They are principally of a blunt, conical form, capped with portions of the marl, and consist of sphe-

roids of basalt, which desquamate in concentric layers, precisely resembling scales of iron. At a short distance up the river, or northward, this marl is covered by a stratified series, dipping at a high angle to the north, and consisting of a yellowish marl, with small imbedded fragments of lignite, covered by a bed of blue clay, containing also fragments of lignite and quantities of an olive-brown earth, in which small pieces of either amber or mineral resin are inclosed. Above this bed is a stratum of red sandstone; and the whole is covered, at its lower extremity, by a thick bed of gravel. These inclined beds reach the level of the water about 400 yards from the basaltic dyke, beyond which the marl again appears in horizontal beds. Southward of the dyke, the change from the broken part to the undisturbed horizontal strata, is much more abrupt, occurring within a very short distance. On the top of the bank adjoining the south end of the dyke the stratified beds of blue clay, &c. are horizontal.

From the above description it appears, that the only place in which the basalt is exposed, is directly under the hill, no trace of it being discernible either above or below this spot; also, that the most compact and extensive mass of basalt is exactly under the highest part of the hill; and that detached masses of igneous rock present themselves, with large portions of the marl adhering to them. A series of stratified beds is also noticed rising from the north towards the hill, meeting the surface at its foot, and is again found in a horizontal position just south of the hill. All these facts surely prove, that the hill must have been elevated by an outburst of igneous matter, which was probably a branch from the basaltic hills to the eastward; one of its forks reaching within half a mile of the spot.

Quantities, of what I believe to be frothy or foam lava, being a brownish black substance, very vesicular or spongiform, extremely light, and somewhat similar to a very porous cinder, are found adhering to the marl, and in the rubble of the bank.

Large blocks of the shelly limestone, composing the summit of the hill, are scattered about its sides and base; and some of them, my guide informed me, fell during the earthquake of 1819; and the abrupt and steep sides are, no doubt, due to the action of water. Numerous fossils are found lying about, characteristic of the nummulitic limestone.

I have minutely described this hill, in the hopes of impressing others with the same belief as myself, of the cause of its elevation.

Near the village of Nambye, in the Charwar range, a basaltic dyke traverses beds of thinly laminated slate-clay and layers of limestone slate. In the immediate vicinity of the dyke the strata dip in all directions, and form

even anticlinal lines. The basalt is very hard, compact, and of a dark blue colour, and presents irregular masses, without the slightest approach to a columnar structure.

Distinct Periods of Volcanic Eruption.—That the volcanic eruptions have occurred at many distinct periods, is also evident, from the different formations with which the igneous rocks are associated, and from the variations in their characters. Thus, in the same section, the lower part frequently consists of large, rolled, or water-worn masses, whilst the upper portion is columnar: in other places the basalt alternates with a calcareous grit or coarse limestone, having a tabular structure, but always distinctly stratified, and very brittle, so as to present perpendicular banks. This limestone is generally associated with basalt, where the latter is raised into hills; and from the fact of *angular* pieces of basalt or igneous matter being imbedded in it, would incline one to believe that, in such cases, it must be contemporaneous, though it often regularly alternates with it. In other places the basalt is interstratified with a pure crystalline limestone or travertin.

The principal mass of igneous rocks (see Map) lies towards the southern department of the province, and forms a group of hills called the Doura range; the intervening spaces and the ground at their southern base generally assuming a porphyritic structure. The northern parts of the range have, for the greater part, a flat, smooth outline; but in the interior of the group are many clusters of small, conical hills, arranged round a circular space, inclosing a kind of hollow. The sides of these cones are very steep, and invariably present innumerable horizontal lines, forming rings resembling narrow paths. The surface being covered with basalt, in very small pieces, is totally devoid of vegetation, and has precisely the appearance of a newly-laid macadamised road. Their interior, however, has a much more solid construction, as is well seen in numerous deep clefts and ravines with which the hills are in all directions intersected.

One of these ravines, near the village of Doonee, is 50 or 60 yards broad, and nearly 100 feet deep; and its perpendicular sides are composed of compact columnar basalt of a greenish grey colour; the columns being perfect polygons, and of a very large size. This rent must have been formed by some convulsion, as it reaches nearly to the summit of the hill; and the only water that could ever have flowed down it being that which falls on its sides and bed, and must be very little.

Alternations of Basalt with Strata of the Upper Secondary Formation.—Near Nurra, on the borders of the Runn, a hill called Jogé-ki-bit, basalt alternates with slate-clay, limestone slate, slaty limestone, and a laminated loam. The strata dip from 40° to 50° to the north, which being

at a higher angle than that at which the hill itself rises, it causes them to crop out; the surface being also broken into several distinct ridges. The igneous rock alternates three times. In one instance it underlies a stratum of hard slate-clay; in another it occurs between a coarse, soft sandstone, and slate-clay, and sandstone slate; and it also forms the conical summit of the hill, which is not more than ten feet in diameter. The basalt desquamates in flakes, but has a centre of compact rock. The same inclination of the beds is continued through the hill.

Alternations of the Calcareous Grit with Basalt.—At the village of Doonee, above mentioned, the banks of the river present a perfectly perpendicular wall, from 15 to 20 feet high, and are composed of the calcareous grit, or coarse limestone alternating with basalt, in the following order: first, grit; then a horizontal bed of rounded pieces of basalt; and next, another stratum of the grit, 15 feet in thickness; the whole being covered by the basalt forming the hills.

Another good example of this alternation is near the village of Keroee, at the eastern limit of the formation. The banks of a river are here composed, in some places, of the basalt forming the Doura range; and in others, entirely of the limestone grit, which in one place overlies the basalt, but forced up into anticlinal lines, as if the igneous rock had been protruded from below; the broken state of the strata showing that it was not originally deposited in this position. The bed of the river at this place is entirely composed of basaltic columns; their horizontal sections forming a regular pavement; and large masses of the columns, occupying from 200 to 300 square yards, and being about eight feet in height, remain every here and there, similar to a field of corn partially reaped. The columns are very regular, generally four-sided, with smooth, even surfaces, and are composed of a hard, compact, dark blue basalt.

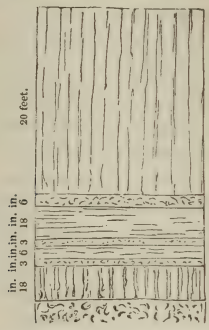
Another instance of the junction of the limestone grit with the basalt is near the village of Choolree, a little to the westward of Kaira. The basaltic range is completely divided by a narrow ravine, in which the two rocks appear in contact, the limestone being broken in all directions. One side of the ravine presents a perpendicular cliff, of nearly 80 feet in height, of irregular columnar basalt, overlying a bed of rounded masses of the same, though the opposite bank is composed of the limestone grit. Advancing through the Pass, the basalt terminates abruptly, and is succeeded by the limestone grit, which forms both sides of the ravine. Further on, the basalt again appears in the form of a dyke; beyond which is the grit, once more succeeded by a dyke of basalt, forming, at this extremity of the Pass, both banks. Where the dykes of basalt occur the limestone lies in immense masses, evidently broken off at the time of the projection of the upper bed of igneous rock; being itself of subsequent formation to the lower basaltic bed of rolled masses. This is very distinctly shown at one part of the Pass; and it should be mentioned, that the bed of the ravine consists throughout of irregular or broken basalt.

The intervening spaces and the ground at the base of these hills are composed, for the most part, of a red clay much resembling brick, a variety of it being amygdaloidal, of a darker colour, extremely hard and tough, and containing quantities of calcareous spar, chalcedony, rock crystal, &c.

In some places it forms low ranges of hills of a hard rock, of a dingy red colour, thickly interspersed with cylindrical kernels of zeolite, with a light green coating, some of them dividing into two parts. Other specimens contain numerous crystals of felspar; and, in many instances, all the mineral substances have disappeared, leaving a vesicular mass. Occasionally, thin beds or layers of calcareous spar, of a leek-green colour, are met with, also of rock

crystal and chalcedony in all its varieties. The surface of the plains is covered with fragments of these minerals, derived from the disintegration of the amygdaloids, which are rapidly affected by exposure to air and water. Some of the sides of the hills are covered with heaps of rock crystal, as if cart-loads had been purposely thrown down.

Alternation of Basalt with Travertin.—A very good example of successive eruptions of basalt occurs near the small village of Wurrowsow, on the south-western flanks of the Charwar range. This point must at one period have been a lake, it being now a dead flat, about 4¼ miles in diameter, and surrounded by low but steep hills, whose surfaces are covered with small fragments of basalt; its general level is about 20 feet above the ground to the east of it. The soil consists of alluvial matter and fine gravel, totally different from the sandy plain by which it is bounded; but its most interesting feature is the basalt at the eastern outlet or break in the low surrounding hills. This mass of trap consists of perfectly polygonal columns about 25 feet in height, but broken into lengths, forming a series of regular steps, cut into a horse-shoe shape by a small stream, which discharges itself during the rainy season. The hills that flank it on each side are composed of a base of coarse sandstone capped by an earthy basalt, a dyke of which, 8 or 9 inches wide, has, in one spot, penetrated the subjacent sandstone. The following is the section exposed in the horse-shoe part of the fall.



The friable basalt forms the base of the fall. Above the columns the bed of the small stream consists of a loose, calcareous calc-tuff.

This section presents several interesting facts; as, from the alternation of basalt with the limestone or travertin, it is evident, that a considerable time must have elapsed between the igneous eruptions. The variety in the texture of the limestone or travertin may be accounted for by supposing, that the waters under which it was deposited were sometimes perturbed, or rendered muddy by a flood; but at other seasons clear, when a pure calcareous precipitate would take place. The basalt forming the columns is very hard, compact, of a dark blue colour, and smooth surface; and it may be traced to some small hills northward of the spot.

Near this place the surface has been affected in a manner worthy of observation. Every here and there, a small spot, varying in size from 3 to 20

yards in diameter, has been raised into a convex form; the pavement, that covers it, consisting of tabular plates of slaty sandstone, broken into small masses; and the fractured lines generally radiating, though in an irregular manner, from a centre. In some places the tops of these little globular elevations have been removed, leaving a regular circle of stones, whose bounding lines are disposed like the stones of an arch. In other instances they assume a more conical shape, resembling small hillocks, from the upper part of which the outer coating or tabular masses have generally fallen away. When they are of a larger character, the whole presents a heap of broken masses of rock.

Denodur Hill, an extinct Volcano.—Of the detached hills, the elevation of which I conceive to be due to volcanic influence, the principal is that called Denodur, and is situated near the shores of the Runn. It is the largest and highest hill in the country, and is evidently the remains of an extinct volcano, an irregular crater being still visible. In the north side is a large gap, reaching nearly to the foot of the hill, but partially blocked up by a lower ridge, or a kind of traverse. Its western flanks are composed of a series of ridges of laminated clay and loam, interspersed with flat, angular fragments of slaty sandstone and slate-clay. The surface of some of these ridges is smooth, consisting either of thin slabs of slate-clay, or of thicker slabs of a very compact, crystalline, and slightly calcareous stone, the same as that which overlies the laminated series, and forms the walls on the Runn, &c. Near the base of the hill and for more than two-thirds up its side the construction alters, being composed partly of a loose sandstone, and partly of the calcareous grit, containing imbedded, angular fragments of basalt; the uppermost part is a perpendicular wall of basalt, which, apparently, continues all round the top. A stream of very compact basalt runs past its north-western flank, and in other places. Numerous small conical hills, composed of horizontal layers of limestone grit, or of basalt, are scattered over its sides, and its base is covered with a thick mould, formed of decayed vegetables, with earthy matter. Nowhere did I find any traces of recent disturbance, although the people of the neighbourhood, particularly the Jogees, or religious devotees, who inhabit a temple on its northern flank, asserted that fire issued from it during the earthquake of 1819. If it did, there would, of course, be some signs of it remaining; but I was unable to penetrate into the interior of the hill, owing to the dense Bauble Jungle, or crooked thorn tree with which it is covered.

Not far from this place, and adjoining the village of Nuckutrana, is a hill of some size, called Ungia-soorud, the elevation of which has also been effected by volcanic agency. The flanks and base are composed of a very loose, friable, calcareous sandstone and grit, apparently stratified, but inclined

at all angles; and the remainder consists of very compact basalt. The hill is divided into two parts by a narrow, tortuous cleft, the sides of which are nearly perpendicular, and composed of irregularly triangular prisms of basalt. The cleft is not more than four feet wide at the bottom, though it is somewhat broader at the top; and as it passes completely through the hill, we must suppose the whole to be similarly composed.

All the other numerous isolated hills scattered over this part of the province, including that called the Nunnaw, next to Denodur, appear to be similarly constructed.

The hill called Lecka, deserves particular notice. It forms one of a group of hills on the borders of the Runn, at the north-western extremity of the province, and is composed of two portions; one consisting of stratified beds of sandstone; and the other wholly of basalt, in irregular, triangular columns. The beds of sandstone are horizontally disposed, and of various colours and textures; the lowest stratum being a coarse, brown, quartzose grit. The igneous rocks crop out in various places near this spot, forming a cluster of small hills between it and the Jooria range; the intervening spaces being broken in the most confused manner.

Recent Outbursts.—Having given as many examples of the elevatory effects of volcanic action as my space will admit, I shall conclude my account of their phænomena with a description of some igneous outbursts of, apparently, a very recent epoch. The principal one occurs at the village of Wagé-ké-Pudda. The spot which has been acted on is a rather high table-land, composed of the nummulitic marl, and is flanked by low, irregular hills of ironstone and gravel, called by the natives Kara Rurraw. The first view of it, is very striking. Conceive a space of about two square miles, blown out into a flat basin, the sides being broken into fissures, with craters, ravines, and hollows; and the interior, or bed of the basin, interspersed with hillocks and cones of every variety of colour, black, red, yellow, and white, and with patches of cinders, similar to the refuse of a furnace; the whole looking as fresh as if the igneous agents were still in operation.

The surface of the table-land immediately surrounding the blown-out space, is covered with a burnt ironstone, divided into irregular cells, similar to Septaria; below which are steep banks, 40 to 50 feet high, consisting of comminuted particles of clay, sand, gravel, scoriæ, and small angular pieces of basalt; the whole being loose, and having a dry and brittle feel.

Within the centre are several small craters, or circular spaces, surrounded by walls of basalt. None of them are perfect circles, being broken through by watercourses; but one has about two thirds of its circumference com-

plete, the sides of which, about forty feet high, are in the upper part quite perpendicular, and consist of very compact basalt, of a columnar structure; while the lower ten feet present a talus, composed of volcanic sand, and scoriæ in very thin laminæ. Below the columnar basalt is a bed of a friable variety, three feet in thickness. In some parts the columns are capped with a thin band of ironstone. The interior of this crater is about 80 yards in diameter, and consists of volcanic sand, with imbedded angular fragments of basalt. The most perfect of these craters, or circular spaces, are generally hid from view, being approachable only by the narrow ravine forming the outlet of the watercourse which cuts through them. The basalt varies greatly in texture and general appearance: in some places it is columnar, exceedingly hard and compact, in others it contains imbedded crystals of felspar, and it occasionally presents the structure and texture of an amygdaloidal clay. Some varieties also consist of concentric layers of a kind of brittle, clayey substance, inclosing a nucleus of hard rock; the whole being imbedded in a mass of clay, which looks as if a number of small roots were entwined about it. All the varieties are frequently found in the same bank or hillock.

Several other small basins have been blown out in the surrounding tableland, forming inverted cones, about 15 or 20 feet in depth; and are composed of the same materials as those just described. Many of them consist entirely of small, brittle particles, of a pale yellow colour, evidently sulphuric. The clay has, in various places, been burnt into a perfect brick; and the marls, or sandy clays, are frequently of a beautiful bright purple. Quantities of talc, or mica, lie scattered about, twisted and contorted into a variety of shapes; and some of the iron ore which covers the surface, appears to have been partially fused, consisting of a spongy, vesicular mass. The whole has the appearance of having been for some time subjected to considerable heat, and then suddenly blown up. The cones and banks of loose volcanic scoriæ must be yearly washing away; and it is difficult to conceive, that the walls of solid basalt forming the sides of the craters, can belong to a similar period, having all the appearance and texture of very old basalt; but it is possible that a recent eruption may have taken place in the site of one of a more ancient date, thus presenting a mixture of old and recent volcanic products. If it is true, that basalt owes its columnar structure to its cooling slowly under a great pressure, it is impossible that these masses of columnar basalt and the loose cones of scoriæ can be contemporaneous.

In the nummulitic marl forming the banks of a river which flows past this patch of blown-up ground, is a stratum of earth containing small nodules or

rounded masses, of a pale yellow colour, translucent and brittle, and which burn with a bright flame, giving out a strong aromatic odour. It is contained in a dry, olive-brown earth, so light as to float in water.

Numerous *Echinodermata*, and other fossils, are found on the table-land, and some of the fields are thickly strewed with casts of a Turbinella of a very large size, the external shell being always wanting. On breaking them, small fragments of igneous matter are found in their interior.

In the table-land just south of the outburst, is a large fissure, about a quarter of a mile in length, 40 yards broad, and 40 or 50 feet deep. One extremity communicates with the river, and the other is rounded, or formed into a basin shape. The sides are perfectly perpendicular; and it is clearly an opening in the ground, there not being the slightest indication of anything of the kind, until directly at its brink. I was informed by a native of the village, (the only present inhabitant,) that smoke issued from the outburst about twenty-two years since; but little dependence can be placed on the statements of these people.

Another similar, but smaller, outburst occurs about three miles south of Mhurr, near the spot in which, in my account of the tertiary deposits, I mentioned that a large basaltic dyke crosses the river. The space here blown out, does not exceed 100 yards in diameter, and 15 feet deep, consisting of similar cones of volcanic scoriæ, and comminuted particles, as above described; but there is no trace of any basalt nearer than the dyke in the river.

From what I have now detailed, it appears, that igneous action has affected all the formations of which the province is composed; and it will also appear, by the following details, that the Grand Runn, the most remarkable feature of the country, owes its peculiar characters to volcanic action.

The Grand Runn.

With a short account of this large and singular tract, I shall conclude the paper. It has been described by Captain Burnes, in a memoir in the library of the Royal Asiatic Society; and referred to, at considerable length, by Mr. Lyell, in his "Principles of Geology*."

This tract, containing an area of upwards of 7000 square miles, exclusive of the space occupied by the Bunnee, and the islands of Puchum, Khureer, &c., is, perhaps, unparalleled in any known part of the globe, as it may be said to be placed on a level between land and water. It is dry during the greater part

* 5th Edit., vol. ii. p. 183 *et seq.*

of the year, when its surface consists of a sandy flat, totally devoid of vegetation; but, perhaps, on account of its saline nature, always sufficiently moist to prevent its particles being drifted. During the prevalence of the south-west winds, however, so much water is blown up its eastern inlet by the Gulf of Cutch, and, at its western extremity, by the eastern branch of the Indus, as to cover its whole surface; augmented by the freshes, which, at the same time, come down the Loonee and Bunass rivers, and the numerous small streams which intersect the northern coast of Cutch. At those seasons, the Runn has all the appearance of a sea, and is passable only on camels, and, in some seasons, with difficulty. It has been described as the dried-up bed of a sea; but it is not easy to account for its drying up, unless we suppose a general depression of the ocean. We must, therefore, look to other causes.

In several parts of the world, particularly in the Baltic, there are undeniable proofs of a gradual rising of the land; and, in time, parts of that sea might be converted into a tract similar to that of the Runn*. It does not become me to inquire whether this gradual elevation is due to a series of so minute elevatory movements as to be unnoticeable, except from the effects which subsequent measurement proves them to have produced, or from a gradual expansion by volcanic heat. But in Cutch we have evidence of movements within a very late date, and every reason to believe that similar ones have occurred at various periods. The earthquake of 1819 is known to have produced a remarkable change on the western extremity of the Runn, by throwing up a mound 50 miles in length, 16 in breadth, and 18 feet high; and by depressing an adjoining tract, so as to convert it, from a cultivated district, into a large salt lagoon. As the changes in level, thus effected, have, however, been detailed in other papers, I shall merely observe, that when I was at Luckput in January, 1834, very little if any change had occurred since Captain Burnes' visit, in 1828; except that the Sindians had repaired all the bunds across the river, and thus, by preventing further supplies of fresh water, the lagoon had assumed much the same appearance as previous to the freshes of 1828.

I was also informed by a boatman, who constantly plied up and down from Ullah-Bund to the sea, that between Sindoo and Sindree (see Map), there is a bank, six miles broad, covered by only one foot of water; and as there is no channel through it, the boatmen are obliged to get out and haul the boats across the bank, after which they follow the windings of the channel to Ullah-

* See Mr. Lyell's Memoir, on the proofs of gradual rising of the land in Sweden. Phil. Trans. 1835, p. 1 *et seq.*

Bund. It would therefore appear that this portion could not have been so much sunk as that around Sindree, and between it and Luckput.

I was also assured that pieces of iron and ship-nails have been thrown up from fissures in the Runn; and Capt. McMurdo* mentions a boat which had been buried under 15 feet of alluvium, having become exposed in a mud-bank, near the village of Wuwania, on the Kattywar side of the Runn, or where it joins the Gulf of Cutch.

The number of places still pointed out as Bunders, or quays, together with the large stones formerly used as anchors, one of which still lies on a small elevation on the Runn, not far from the Puchum Island, and the confident assertion of all the inhabitants on its coast, tend to confirm the opinion that the district must once have been covered by a navigable body of water.

Some parts of the shores have precisely the appearance of having been recently deserted by the sea. This is particularly the case near the village of Charee, which is separated from the Runn by a low range of hills. To the northward of this range is an inlet, about one mile and a half in breadth, and it looks precisely like a small creek or bay from which the tide has just ebbed. Its surface is composed of smooth, whitish clay, with numerous scattered gravel banks, the ends of which have been worn round, and the sides present perpendicular or overhanging banks. Several masses of crystalline sandstone also rise suddenly out of the bed; and some of them consist of immense fragments, which look as if they had been piled one on the other, and have a strange effect from a short distance. Beyond the inlet is another range of hills of the same description, but it is more broken and confused than any other in the country. In some places, the upper stratum of hard rock has been thrown into a position like the roof of a house; in others, it precisely resembles a ruined fort with towers on a hill; but the greater part of the stratum is a confused assemblage of huge fragments of rock. Northward of this range, and separated from it by a narrow belt of the Runn, is a steep conical hill, called Keera, 600 or 700 feet in height, consisting partly of the same materials as the others, and partly of basalt; and it appears to have been formed in a similar manner to the hill called Ungur-soorud, before described, and others of that class. It is also more than probable, that the peculiar, fractured appearance of all the ranges is due to the same cause acting at the same period.

Supposing the bed of the Runn to have been raised by a series of violent movements, such as must have upheaved the Keera, and its surface to have

* Extract from Captain McMurdo's MS. memoir on Kattywar, in Captain Burnes' Travels in Bokhara, vol. iii. p. 329, *note*.

been broken, and covered with fragments of rock, its present level outline may be ascribed to subsequent operations. The Runn is bounded to the north, as already stated, by the Thur or Little Desert, a district composed entirely of sand. The Loonee and Bunass rivers also flow through a sandy soil, as do many other streams which enter from the Cutch side. Now, during the periodical floods, vast quantities of sandy alluvium must have been brought down by these rivers, deposited at their mouths, and washed thence and spread over the surface of the Runn by the sea-water annually blown up at its eastern and western extremities. This operation, repeated yearly, would fill up all inequalities, and produce in time a level surface. It is probable, however, that the present state of the district may also be, in some measure, owing to a gradual rising of its bed, as it is only to such operations that some of its shores, as those of the inlet above mentioned, can be ascribed.

There are also many facts to prove, that this tract has been elevated at very different periods. The high hills bordering its southern shore are, as before stated, composed principally of the laminated series, and their surfaces are covered with Ammonites, Nautilites, Belemnites, and other fossils of that geological period; whereas along its immediate line of shore, there are generally low ridges, composed of rocks full of marine remains of a totally different character, many of them belonging to existing species. Numerous small rocky islets, consisting of shells agglutinated into a solid mass, occur in various parts of the Runn, and are barely raised above its present level. They are probably merely the higher portions of large tracts, the lower parts of which are covered by sediment.

Natural Walls on the Runn how formed.—Still more striking instances of the effects of upheavement, since the Runn assumed its present characters, are exhibited in the detached, elevated masses of rock which I have called the *Natural Walls* on the Runn.

They consist (see woodcuts) of disconnected portions of rock rising abruptly from the surface of the Runn, and presenting a smooth, vertical wall, occasionally upwards of thirty feet in height, and in one instance upwards of two

End view of a wall, about 15 feet high, and two miles long.

miles in length. Some of them resemble domed or vaulted buildings, the

Dome-shaped wall.

reversed side consisting of a talus of broken fragments of rock and soil.

One of the walls on the Runn, about 30 feet high, the stones divided into masses, but not broken.

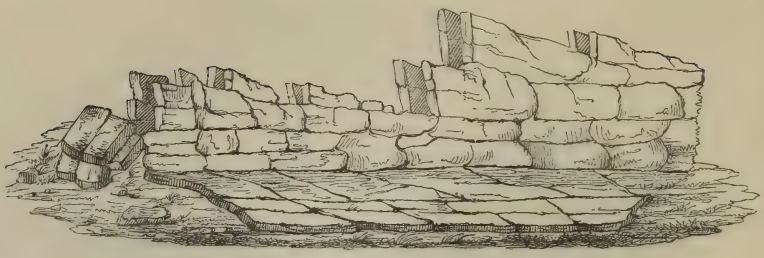
Side view of the same, showing the stones on end.

Two walls on the Runn, forming a semicircle, but sloping outwards.

In one place these walls form a semicircle about 500 yards in diameter, both walls sloping outwards. That the walls have been uplifted into their present form is quite evident, first, from the stones being all on end, that is, with the grain in the direction of their present position, and peeling off in scales down the face of the wall; and secondly, from my having met with the same phenomena on a smaller scale, in other parts of the country, where the slabs of rock are at all angles, and even, as those before mentioned, turned over. It should be noticed, also, that the borders of the Runn, near these walls, are composed of friable beds of the laminated series, covered with thick tabular masses of hard sandstone, precisely similar to those forming the walls.

Had they been uplifted during the permanent prevalence of the waters, the sloping talus of earth and fragments of rock, with which they are all backed, must have been washed away. It should be stated, that these examples are situated on ground now almost recovered from a state of Runn; some parts having been sufficiently augmented by means of the sandy alluvium, washed down from the neighbouring hills to support vegetation; whereas the isolated rocks, several of which rise out of that part of the Runn, and are still subjected to inundation, have no detritus or talus, but present smooth walls of perpendicular rocks. I could never perceive any water-marks on them, nor any remains of marine testacea, which might occur, had the sea ever washed the present level of their foot. It is probable that their origina base lines have become obliterated by the sediment which must have accumulated round them in course of time, and which forms the existing surface.

A very good example of a similar wall occurs in the centre of the province, near the village of Rampoora; it is a ridge of coarse sandstone about 300 yards in length, and from 10 to 15 feet in height, the stones being evidently placed edgeways, and in so regular a manner as to resemble precisely an artificial wall. It rises from a base of the same sandstone, and on one side it



Wall of sandstone near Rampoora.

is nearly flat, but broken into masses, while on the other side are heaps of stone, broken and confused, and the interstices are filled with sand and small trees. At the extremity of the wall the stones slope up like the end of a roof. In the immediate vicinity of this wall is a small range of basaltic hills, striking however at right angles to the direction of the sandstone ridge.

Some of the rivers which flow towards the Runn from the Cutch side are lost in the sand at their mouths; though at a short distance up the bed of the river, the stream runs freely. It would thus appear, that at these spots, the bed of the Runn has been increased, by the sediment, probably, brought down by the stream; but so loose is the soil, that the water soaks into it and even flows under it, instead of wearing channels. This phenomenon is observable in the sandy beds of many of the rivers in the province. The stream may be noticed running with some rapidity and of a sudden to cease, the bottom of the river presenting a smooth sandy surface; but a mile lower down the water again issues and continues its course; the intervening parts being sometimes quite hard and dry; in others forming very dangerous quicksands.

The natives have various traditions that the drying up of this sea was sudden, and that boats were tossed on the land and wrecked; they pretend also to assign a date to this event, but their accounts differ so materially and are so vague, that not the slightest reliance can be placed upon them, except to the general fact.

It is evident that the Runn could not have been drained by the bursting of its boundaries, at least since it was deep enough to be navigable; because its present surface, notwithstanding the sediment which yearly accumulates on it, is even now so little raised above the sea's level as to be flooded by the mere effects of the wind; but the most probable supposition is, not that it was ever a detached inland sea or lake, but that it communicated with the ocean by its present outlets, and that its bed has been raised, partly perhaps by a gradual movement, and partly by violent upheavements during

earthquakes. Even such marked changes of level as the raising of Ullah Bund, and the sinking of the ground near the large town of Luckput, would have passed unrecorded but for the accidental circumstance of the district having been visited by a British officer. Other portions of this vast area, the greater part of which is never traversed by man, may have been similarly affected at that time, and yet the changes remain unknown.

Successive Marine and Freshwater Beds.—The submerged tract near Luckput, or Lake of Sindree, may, I think, illustrate the manner in which successive marine and freshwater deposits may be produced. This tract was at one period a richly cultivated district, periodically flooded by a branch of a great river, and produced large quantities of rice. In this state numerous land testacea no doubt occupied it, and were mixed with the remains of fluviatile species brought down by the floods. The bones of animals used in agriculture, and those of various domestic species, also the remains of broken pottery, perhaps coins, and other proofs of civilized life, might likewise have been imbedded. Suddenly, owing to the damming up of the river by the Sindians, the supply of fresh water ceased, and the tract was no longer cultivated or inhabited. Some time after this an earthquake occurred, uplifting one part and depressing below the level of the ocean another, which was immediately converted into a salt lake. A perfectly new description of deposit and organic remains must then have been accumulated, consisting wholly of marine animals, principally such as inhabit shallows and tide-ways. Again, owing to the sudden melting of the snow on far distant mountains (the Himalayahs) the waters of the river came down with such force as to burst all the bunds built across it, as well as that thrown up by the earthquake, and covered the tract with fresh water, or perhaps with fresh at its upper or northern extremity, and brackish at its southern near the sea. Supposing this state of things to have remained for some time, the river continuing to pour its water into this lagoon, another change would take place in the description of the sedimentary deposit. Once more the bunds were erected across the river, the supply of fresh water ceased, and as that on the lagoon evaporated, the sea again flowed in and converted it into a salt lake, which is its present state. All the above changes are known to have occurred ; and it is easy to suppose that if the shallow part at Sindoo were slightly raised above its present level, thus shutting out the sea, the part around the Fort of Sindree would be converted once more into dry land. If, therefore, at any future period, the river should again cut a channel, the banks might present various, regular beds alternately enclosing marine and freshwater exuviæ, the latter being also associated with land productions.

The ruins of one of the towers of the Fort of Sindree remained, when I visited Luckput in 1834, and in all probability now stand as a monument of the changes, which are daily taking place on the earth's surface.

Conclusion.—In concluding this paper, I have only to observe, that I have throughout endeavoured to describe facts as they appeared to me at the time I examined them, without regard to any particular theory; and if I have failed in making my descriptions intelligible, I have only to plead the difficulty of having had a great deal to describe in a limited space. As the country to which this memoir relates is, however, unfortunately from its geographical position, beyond the reach of general observers, I am induced to hope, that this sketch, however imperfect, may be found to possess some interest.

For the arranged list of fossil shells, given in the Appendix, as well as for all my information on that subject, I am entirely indebted to Mr. James De Carl Sowerby, who had my specimens (now in the cabinets of the Geological Society) for some time in his possession for examination.

The woodcuts are copied from drawings taken by myself on the spot, for the express purpose of geological illustration, and are unexaggerated views of what they are intended to represent.

December 31st, 1836.

APPENDIX.

SYSTEMATIC LIST OF ORGANIC REMAINS, THE PLANTS DETERMINED BY MR. JOHN MORRIS, AND THE REMAINDER BY MR. JAMES DE CARL SOWERBY, A.L.S.

The fossils considered as belonging to previously described species, are distinguished by a reference to the work in which they were first noticed; the new species are described in the explanation of the plates at the end of the part.

Class, Genus, and Species.	Plate.	Formation.	Locality.	Remarks by Capt. Grant.
Plantæ.				
Ptilophyllum acutifolium	XXI. 1 a—3.	Sandstone, Clay with Coal.	South of the Charwar range.	
——— *Cutchense*	XXI. 4.			
Lycopodites affinis	XXI. 5.			
Fucoides (Codites?) dichotomus	XXI. 7.			
Stems of Equisetites or a Monocotyledonous Plant .	XX. 1 b, 6.			
POLYPARIA.				
Lycophris Ephippium..... (p. 300 *Orbitolites.*)	XXIV. 15, 15 a, b.	Nummulitic group.	Baboa Hill and Wagé-ké-pudda.	Very abundant.
——— *dispansus*	XXIV. 16, 16 a, b.	.....Ibid.....		
RADIARIA.				
Crinoidal stems	XXIII. 14-16.	Upper Secondary	..... Charee	Found on hills near Charee with Ammonites and other fossils.
Echinus dubius.....	XXIV. 18.	Nummulitic group	Baboa Hill, Wagé-ké-pudda.	
Galerites pulvinatus	XXIV. 19.	.....Ibid.....	..... Baboa Hill	
Clypeaster affinis ? ..... Goldfuss, XLII. 6.	XXIV. 20, 20a	.....Ibid.....	Ibid. and near Joongrea.	
——— *varians*	XXIV. 21, 21a	.....Ibid.....	Ibid. and Wagé-ké-pudda.	
——— *depressus*	XXIV. 26, 26a	..... Tertiary	.....Soomrow.....	Found in great numbers, and similar in colour and form, to recent specimens, but flatter.
——— *oblongus*..... Lamk.	XXIV. 25, 25 a.	.....Ibid.....	Between Joongrea and Kotra.	
Spatangus obliquatus ..... S. Buckl. ? Goldf., XLVII. 6.	XXIV. 22, 22 a, b.	Nummulitic group	..... Baboa Hill	Very numerous.
——— *acuminatus?*..... Goldf., XLIV. 2.	XXIV. 23, 23 a—c.	.....Ibid.....	.....Ibid.	
——— *elongatus*	XXIV. 24.	.....Ibid.....	.....Ibid.	
ANNULATA.				
Serpula ? recta	...XXV. 1. ...	..... Tertiary	.... Near Kotra	Bodies of similar form occur in vast quantities on isolated banks in the river near Kotra.
Siliquaria Grantii.....	...XXV. 2. ...	..... Tertiary	Borders of the Runn.	
CIRRIPEDA.				
Balanus sublævis.....	...XXV. 3. ...	.....Ibid.....	.....Soomrow.	
CONCHIFERA.				
Pholadomya ? inornata	... XXI. 8. ...	..Upper Secondary..	.... near Charee	Found on some hills bordering the Runn, which have been much disturbed by volcanic action.
——— *granosa*	... XXI. 9. ...	.....Ibid.....	.....Ibid.....	
——— *angulata*.....	...XXI. 10....	.....Ibid.....	.....Ibid.....	
Amphidesma? ovale	...XXI. 11....	.....Ibid.....	.....Ibid.	
——— *? hians*	...XXI. 12....	.....Ibid.....	.....Ibid.	
Corbula lyrata	...XXI. 13....	.....Ibid.....	.....Ibid.	
——— *trigonalis*	. . XXV. 4. . .	..... Tertiary	Borders of the Runn.	
——— *rugosa*	. . XXV. 5. . .	....Ibid.....	.....Ibid.	
Tellina exarata	...XXV. 6. ...	.....Ibid.....	.....Soomrow.	
Astarte unilateralis	...XXI. 14....	..Upper Secondary..	..... Charee.	
——— *pisiformis*	...XXI. 15....	.....Ibid.....	.....Ibid.	
Venus granosa	...XXV. 7. ...	..... Tertiary	.....Soomrow.	
——— *cancellata*.....	...XXV. 7*....	.....Ibid.....	.....Ibid., Kotra.	
——— *nonscripta*.....	...XXV. 8. ...	.....Ibid.....	.....Soomrow.	
Pullastra ? virgata	...XXV. 9. ...	.....Ibid.....	.....Ibid.	
Cardita intermedia? ..... Brocchi, XII. 15.	. XXV. 10. .	.....Ibid.....	.....Ibid.	

Class, Genus, and Species.	Plate.	Formation.	Locality.	Remarks.
Trigonia costata, var. M. C., LXXXV.	XXI. 16.	Upper Secondary.	Charee.	Found in the same hills with the Pholadomyæ.
——— *pullus*	XXI. 17.	Upper Secondary.	Charee.	Found in the same bed as *Trigonia costata.*
Cardium intermedium	XXIV. 1.	Nummulitic group	Baboa Hill.	
——— *ambiguum*	XXIV. 2.	Ibid.	Ibid.	
——— *triforme*	XXV. 11.	Tertiary	Soomrow.	
Cucullæa virgata	XXII. 1, 2.	Upper Secondary.	Hubbye Hills.	A pass in the hills between Hubbye and Joorun is paved with these shells imbedded in a hard rock.
Arca hybrida	XXIV. 3.	Nummulitic group.	Baboa Hill.	
—— *radiata*	XXV. 12.	Tertiary	Soomrow.	
—— *tortuosa?* Linn.	XXV. 13.	Ibid.	Ibid.	
Pectunculus pecten	XXIV. 4.	Nummulitic group.	Baboa Hill.	
Nucula tenuistrata.	XXII. 3.	Upper Secondary.	Hubbye Hills.	In the same masses with *Cuc. virg.*
——— *? cuneiformis*	XXII. 4.	Ibid.	Charee.	These shells form stony banks which project slightly above the bed of the Runn; also solid rocks in the Hubbye Pass.
——— *Baboensis*	XXIV. 5.	Nummulitic group.	Baboa Hill.	
Pecten partitus	XXII. 5, 5 a.	Upper Secondary.	Hubbye Hills.	
——— *lævicostatus*	XXIV. 6.	Nummulitic group.		
——— *Soomrowensis*	XXV. 14.	Tertiary	Soomrow.	
——— *articulatus*	XXV. 15.	Ibid.	Banks of the Runn.	
Plicatula pectinoides	XXII. 6.	Upper Secondary.	near Charee.	
—— ——— M. C., CCCCIX.	XXII. 9. a.	Ibid.	Katrore Hill.	
Exogyra conica M. C., XXVI., DCV.	XXII. 7.	Ibid.	Ibid.	
Gryphæa globosa? M. C., CCCXCII.	XXV. 16.	Tertiary	Kotra.	
Ostrea Marshii M. C., XLVIII.	XXII. 9.	Upper Secondary.	Katrore Hill, Charwar range.	Found in a bank in the hill.
——— *carinata ?* M. C., CCCLXV.	XXII. 8.	Nummulitic group.	Charee.	
——— *callifera?* Lamk.	XXIV. 7.	Ibid.	Wagé-ké-pudda.	Isolated banks in the broad river-bed near Kotra are completely covered with these oysters.
——— *orbicularis*	XXIV. 8.	Ibid.	Luckput	Masses, 15 to 20 feet thick, composed of this shell are scattered in the bed of the river.
——— *angulata*	XXV. 17.	Tertiary.	Kotra.	
——— *Flabellulum* M. C., CCLIII.	XXV. 18.	Ibid.	Cheeosir.	The banks of a river near Cheosir are composed of a grit full of these fossils, and of a Cardium. They are generally distributed through the tertiary district.
——— *tubifera*	XXV. 19.	Ibid.		
——— *lingua*	XXV. 20.	Ibid.	near Joonagrea and Kotra.	
Terebratula intermedia, var. M. C., XV. 8.	XXII. 10.	Upper Secondary.	Charee.	
——— *biplicata, var.* M.C.,XC.&CCCCXXVII.	XXII. 11.	Ibid.	Jooria Hill.	
——— *sella, var.* M. C., CCCCXXXVII. 1.	XXII. 12.	Ibid.	Pass of the Hubbye Hills.	
——— ——— *concinna?* M. C., LXXXIII. 6.	XXII. 13.	Ibid.	Jooria Hill.	
——— *nobilis*	XXII. 14.	Ibid.	near Charee.	Very numerous.
——— *dimidiata?* M. C., CCLXXVII. 5.	XXII. 15.	Ibid.	Ibid, Jooria Hill.	One specimen was found in gold-coloured oolite, in the highest part of the Jooria Hill on the borders of the Runn.
——— *major*	XXII. 16.	Ibid.	Charee.	
MOLLUSCA.				
Bulla lignaria, Linn.	XXVI. 1.	Tertiary	Soomrow.	From the lower part of the hills. The shells found in this position differ from those in the highest part of the same hills, and appear to have been deposited in the shores of the Runn since those hills were raised.
Neretina grandis.	XXIV. 9.	Nummulitic group.	Wagé-ké-pudda.	
Natica obscura	XXVI. 2.	Tertiary	Soomrow.	
——— *callosa*	XXVI. 3.	Ibid.	Ibid.	
Globulus obtusus	XXIV. 10.	Nummulitic group.	Baboa Hill.	
——— *? anguliferus*	XXVI. 4.	Tertiary	Borders of the Runn	
Solarium affine	XXVI. 5.	Ibid.	Soomrow.	Very numerous.
Trochus cognatus	XXVI. 6.	Ibid.	Ibid.	
Turritella angulata	XXVI. 7.	Ibid.	Ibid.	Very numerous.
——— *assimilis*	XXVI. 8.	Ibid.	Ibid.	
Terebra reticulata	XXVI. 9.	Ibid.	Ibid.	
Cerithium rude	XXVI. 10.	Ibid.	Ibid.	Numerous, but imperfect.
——— *corrugatum*	XXVI. 11.	Ibid.	Ibid.	

Class, Genus, and Species.	Plate.	Formation.	Locality.	Remarks.
Fusus ? granosus	XXVI. 12.	Tertiary	Soomrow.	
—— *lævisculus*	XXVI. 13.	Ibid.	Ibid.	
—— *nodulosus*	XXVI. 14.	Ibid.	Ibid.	
——, or *Murex hexagonus*	XXVI. 15.	Ibid.	Ibid.	
Ranella bufo	XXVI. 16.	Ibid.	Ibid.	
Rostellaria rimosa M. C., XCI., not Lamk.	XXVI. 17.	Ibid.	Ibid.	
——— *rectirostris*, Lamk.	XXVI. 18.	Ibid.	Ibid.	
Strombus deperditus	XXVI. 19.	Ibid.	Ibid.	
——— *nodosus*	XXVI. 20.	Ibid.	Ibid.	
Cassis sculpta	XXVI. 21.	Ibid.	Ibid.	
Buccinum pumilum	XXIII. 1, 1 a.	Upper Secondary?	Mhurr.	Found in a mass of white marl.
Turbinellus bulbiformis	XXIV. 11.	Nummulitic group.	Wagé-ké-pudda.	Found in vast quantities, and sometimes very large.
——— *affinis?*	XXVI. 22.	Tertiary	Soomrow.	
Mitra scrobiculata? Brocchi.	XXVI. 23.	Ibid.	Ibid.	
—— *fusiformis*	XXVI. 24.	Ibid.	Ibid.	
Voluta jugosa	XXVI. 25.	Ibid.	Ibid.	Among the most numerous fossils found at Soomrow.
—— *dentata*	XXVI. 26.	Ibid.	Ibid.	
Cypræa depressa	XXIV. 12.	Nummulitic group.	Baboa Hill.	
—— *humerosa*	XXVI. 27.	Tertiary	Soomrow.	
—— *prunum*	XXVI. 28.	Ibid.	Eyerau.	
—— *digona*	XXVI. 29.	Ibid.	Soomrow.	
—— *nasuta*	XXVI. 30.	Ibid.	Ibid.	
Seraphs		Nummulitic group.	Baboa Hill.	An imperfect cast.
Terebellum obtusum	XXVI. 31.	Tertiary	Soomrow.	
Oliva pupa	XXVI. 32.	Ibid.	Ibid.	Found in great quantities.
Conus brevis	XXVI. 33.	Ibid.	Ibid.	Very numerous.
—— *militaris*	XXVI. 34.	Ibid.	Ibid.	
—— *catenulatus*	XXVI. 35.	Ibid.	Ibid.	
—— *marginatus*	XXVI. 36.	Ibid.	Ibid.	
Belemnites canaliculatus? Schlotheim	XXIII. 2.	Upper Secondary.	Charee.	
——— ——— ———	XXIII. 3.	Ibid.	Ibid.	
Nautilus hexagonus? M. C., DXXIX.	XXIII. 4.	Ibid.	Ibid.	
Ammonites Herveyii, var. M.C., CXCV.	XXIII. 5.	Ibid.	Ibid.	Ammonites are exceedingly numerous throughout the district coloured in the map, as Upper Secondary, and are generally loose on the surface. In the text (p. 297) eight species are mentioned as new, but on further examination two of them have been ascertained to be only varieties.
——— *elephantinus*	XXIII. 6.	Ibid.	Ibid.	
——— *formosus*	XXIII. 7.	Ibid.	Ibid.	
——— *lamellosus*	XXIII. 8.	Ibid.	Ibid.	
——— *Opis*	XXIII. 9.	Ibid.	Ibid.	
——— *arthriticus*	XXIII. 10.	Ibid.	Ibid.	
——— *ignobilis*	XXIII. 11.	Ibid.	Ibid.	
——— *corrugatus?* M.C., CCCCLI.	XXIII. 12.	Ibid.	Ibid.	
——— *armiger*	XXIII. 13.	Ibid.	Ibid.	
Nummularia acuta	XXIV. 13, 13a.	Nummulitic group.	Luckput	Nummularia are so abundant as almost to compose a large tract on the north-west frontier of the province.
——— *obtusa*	XXIV. 14, 14 a.	Ibid.	Wagé-ké-pudda.	
Fasciolites, (Parkinson) elliptica.	XXIV. 17, 17a.	Ibid.	Ibid. Baboa Hill.	

XXVI.—*On the Upper Formations of the New Red Sandstone System in Gloucestershire, Worcestershire, and Warwickshire; showing that the* Red *or* Saliferous Marls, *including a peculiar* Zone of Sandstone, *represent the* "Keuper" *or* "Marnes Irisées;" *with some account of the underlying Sandstone of Ombersley, Bromsgrove, and Warwick, proving that it is the* "Bunter Sandstein" *or* "Grès Bigarré" *of Foreign Geologists.*

By R. I. MURCHISON, Esq., V.P.G.S. and
H. E. STRICKLAND, Esq., F.G.S.

[Read June 14, 1837.]

PREFACE.

In former communications to the Geological Society*, the System of the New Red Sandstone of Gloucestershire, Worcestershire, and Shropshire was subdivided by Mr. Murchison in the following manner:

	Foreign Equivalents.
1. Marls with salt, gypsum, and a thin course of sandstone ..	*Keuper—Marnes Irisées.*
2. Quartzose, red sandstone, and conglomerate.....	*Bunter Sandstein—Grès Bigarré.*
3. Calcareous conglomerate=magnesian limestone	*Zechstein.*
4. Lower new red sandstone	*Rothe-Todte-Liegende.*

The objects of this Memoir are to describe with greater precision than had been previously attempted, the two superior members of this group, by showing that they are both fossiliferous, and that they can be separated from each other by their zoological and lithological characters, as well as by geological position. The communication is the result of a joint examination of the district, and of other observations made independently by the authors. In it, they propose to describe the prominent characters of the two superior formations of the New Red System as exhibited in Gloucestershire and Worcestershire, and to extend their remarks concerning those beds into Warwickshire. The strata will be considered in descending order.

* See Proceedings, vol. i. p. 471. March 27th, 1838; vol. ii. p. 115. January 21st, 1835; and "The Silurian System," p. 27 *et seq.*

§ 1. *Saliferous Marls and Sandstone* (*For. Syn. Keuper—Marnes Irisées.*).

Having examined the junction-beds between the lias and the new red sandstone from the southern extremity of Gloucestershire through Worcestershire into Warwickshire, we have only to repeat what was adduced by one of us on previous occasions, that in many positions the lowest calcareous band or "limestone of the lower lias shale" is also underlaid by shale, which passes into the new red system by alternations of whitish sandy marlstone, black shivery schist, and greenish marls, with occasional courses of very thinly laminated, flag-like sandstone. The uppermost zone of the new red system, beneath these junction beds, is composed of whitish-green marl, and is succeeded by red marl, which passes downwards, alternating frequently with party-coloured marls, though red for the most part predominates. As the country, occupied by these marls, presents few steep acclivities or neatly cut escarpments, it is not often easy to estimate, with precision, the depth beneath the junction lias beds at which a change of mineral character is first perceived; but we may state, that a zone of sandstone rises, at many places, from beneath the upper portion of these marls. This Keuper sandstone we have detected at intervals, and we have laid it down on the accompanying Map (See Plate XXVII.). It lies at a distance varying generally from half a mile to three miles, from the lowest edge of the lias, the distance changing with the angle of inclination of the strata; its relative position being also dependent on dislocations along the boundary line. There are, however, localities where this sandstone is covered by a considerable thickness of red marl; and by prolonging the course of the strata beneath adjoining platforms of lias, we have been enabled to estimate, that this sandstone is separated from the lias by at least 200 feet of red and green marls. It was stated, on former occasions, that this rock appears in Gloucestershire, at Tibberton, in the form of sandy marlstone, and that it re-appears at Burge-hill* quarries, near Eldersfield, at the southern extremity of Worcestershire. (See S.W. corner of the Map, Pl. XXVII.). The section of these quarries is,

1. Red marl about		4	Feet.
2. Greenish grey marl		5	—
3. Thinly laminated marl, with white gritty sandstone	2		—
4. Soft white sandstone	6		—
5. Greenish and grey marly sandstone	8		—
	—	16	
Dip 10° towards the south.		25	

* This place, though spelt Burg-hill on the Ordnance Map, is invariably pronounced with the soft *g*.

The sandstone beds thin out; and their surface often presents ripple marks. The marls in the bed No. 3 were much cracked at the time of their deposition, for the crevices are filled with whitish sandstone, in the same manner as septaria are occupied by calcareous spar. Sometimes the marl is more broken up, and detached angular fragments are imbedded in the sandstone. The general relations of the Burge-hill sandstone to the surrounding formations is shown in Section, Pl. XXVII., fig. 1.

This sandstone rock, as before stated, is also exposed distinctly at Ripple, three miles north of Tewkesbury. To the north of Ripple it appears gradually to thin out; and in a section at Old House Farm, south of Spetchley, near Worcester, it is represented by only about twelve feet of grey shivery marls with thin courses of sandstone, the whole reposing on red marl. It is also seen half a mile east of Spetchley at the junction of the Alcester and Evesham roads. It is not discernible further north, being lost or obscured amidst the great mass of red marl in which it is enclosed. We, therefore, proceed to describe the characters of the rock at Inkberrow, about twelve miles east and by north of Worcester, in which neighbourhood it has long been quarried, and is so clearly exposed, that it appears to us to afford the best lithological type of the subdivision in Worcestershire.

The sandstone of Inkberrow occupies a prominent part of a distinct ridge about three miles in length, and varying in height from 210 to 320 feet (above the sea), and it extends from the quarry pits, north-west of Radford, in a low hummock, one mile west of Inkberrow by Penhills to Morton Hill, as a culminating point, whence the ground lowers to Feckenham on the north. The same stone re-appears, at intervals, in an attenuated form to the north of Feckenham, ranging by Lower Berrow, and wrapping round a bay of lias, from beneath which, it rises at Wallhouse Farm, at an angle of 20° to 25°. (See Section, fig. 2.)* Near Inkberrow the sandstone is quarried at three chief localities, viz. the Quarry Pits, Stone-Pits, and Mucklow's Grave. It is also clearly exposed on the sides of any of the lands, descending from the ridge of red ground on the east to the vale of lias on the west†. The following section exhibits the whole of the strata here exposed. (See Pl. XXVII., Section, fig. 3.)

1. Red and green marls occupying the crown of the ridge, estimated thickness 100 to 120 Feet.

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* Owing to the undulations of the red marl in which it is contained, the same rock is again brought out at Love Lane, about two miles to the east.

† This plain of lias, bounded on the east by hills of red marl, indicates a line of fault which is traceable from Bredon Hill on the south towards Bromsgrove Lickey, and has been described by Mr. Strickland, Geol. Proc. vol. ii. p. 5, and Analyst, vol. ii. p. 1.

2. Sandstone, consisting in detail of
   - *a.* A cover of finely laminated flag-like marly sandstone, of delicate greenish and light drab colours, alternating with marls..... 20 to 30 Feet.
   - *b.* Thick-bedded, finely laminated, soft, siliceous sandstone, of various colours, the prevailing one being a white or pinkish white, with occasional tints of green, purple, &c..... 15 to 30 —
   - *c.* Finely laminated flag-like sandstones, similar to *a.* ....
3. Red and green marls similar to No. 1.

These sandstones, though usually of a white or lightish colour, exhibit so many lithological varieties, that their characters can, with difficulty, be rigorously defined.

At the Great Quarries or Inkberrow Stone Pits, there are several excavations exposing surfaces of the rock from 30 to 40 feet in depth. The chief or central beds are brownish red, brownish yellow, rusty pink, delicate pale green and white, the same tint being seldom persistent for more than a few yards in horizontal extension. The quality of the stone also varies very much, in short distances. A sandstone of a fine grain and good quality sometimes thins out and terminates in soft marly beds, whilst wedge-shaped masses of marl are dove-tailed with the sandstone. The very great variety of the rock is well seen in the tombstones, piled up for sale. From these the purchaser may select slabs of five or six distinct tints, varying from nearly a pure white to a deep purple; each slab being for the most part of one colour. This uniformity, however, extending only to the length of a large tombstone and to the depth of four or five inches, is due to the fine lamination of the beds, and the effect, though evident to the depth of a few inches, disappears where the rock is quarried for troughs or building purposes, when various tints and zones occur in the *same* block. It is, however, essential to remark, that although blotches of marl appear at intervals to certain depths, the rock is never spotted red and green like many of the inferior sandstones, whether of the new or of the old red systems. In the quarry at Mucklow's Grave, the upper flag-like beds are underlaid by sandstone, which weathers to brownish yellow colours with dark ferruginous stripes, marking the laminæ of deposition, the edges of the stone being sometimes worn into cavities. The thin way-boards are of green and deep red colours, and they sometimes cover rippled surfaces of the rock, on which are often raised, serpentine strings of sandy marl. Occasionally, these assume the forms of Septaria, the fine sand penetrating irregularly in minute and sinuous courses through the marly way-boards. In some instances, these layers of clay appear to have been cracked before the sand was accu-

mulated; in which respect, they precisely coincide with the beds at Pyle in Glamorganshire, recently described by Dr. Buckland as Keuper sandstone. At this spot, the best building material is a white sandstone, composed of rounded grains of quartz with specks of whitish decomposed felspar, having in some parts a delicate pink tinge. The mass cuts into blocks two feet thick.

The same sandstone, subordinate to the marls, is seen near Harvington, south of Inkberrow, where it was formerly worked; also between Ragley and Alcester, and at numerous localities in the western part of Warwickshire. At Oversley Lower Lodge, near Alcester, it caps a platform about one mile and a half from the lias escarpment. The quarry there presents the following section:

1.	Red marl	4 Feet.
2.	Grey marl	4 —
3.	White sandstone with laminæ and fragments of greenish marl.	6 —
4.	White sand with veins of gypsum.	
5.	Red marl to the foot of the hill.	

A similar sandstone also caps the great Alne Hills, ranging parallel to a narrow outlier of lias, which extends north-west from the main body of that formation. There are here indications of an upcast of the red marl, ranging from near Stratford-on-Avon towards the north-west*. On the north of this line of fault near Knowle, (North boundary of the Map, and Section, fig. 4.) distant full eleven miles from the chief escarpment of lias on the south, is a kind of basin of red marl, with a small outlier of lias in its centre. On the east this basin is bounded by a fault which appears to strike northwards from Warwick, while its northern margin is obscured by the great prevalence of quartzose gravel in that direction. The stratum of sandstone above described occurs within this area at the following points:—Mouse-hill, near Tanworth; Lapworth, Knowle, Rowington, Shrewley Common, Barnmoor near Claverdon; and Wolverton. At these localities its mineral character and geological position distinguish it from the sandstone of Warwick, which underlies the marls, and identify it with the sandstone of Inkberrow, Ripple, and Burge-hill. One of its most distinguishing lithological characters, is the abundance of greenish marl, which separates the sandstone into finely laminated beds, rarely fifteen inches thick and commonly much less. The marl is often intersected by the thin sinuous veins of sandstone resembling septaria, before alluded to, a character which, both in Warwickshire and

* We may hereafter endeavour to show that this as well as several other lines of dislocation terminate in the Lickey Hills.

Worcestershire, seems to distinguish this upper bed of sandstone from the lower one which occurs at Warwick. This sandstone is also more variable in its texture than that of Warwick, for though *hand* specimens may be found much resembling the latter in appearance, yet in some of the beds a coarse grit prevails, similar to that of Burge-hill.

The best place for studying this sandstone in Warwickshire, is at Shrewley Common, about four miles north-west of Warwick, where it occurs near the summit of an extensive platform of red marl. The great thickness of this underlying marl, is evident at Hatton Hill, which is wholly composed of it. At Shrewley Common, the sandstone is exposed by a tunnel, on the Birmingham and Warwick canal, and in some adjacent quarries. The following section is visible:

Red marl	30 to 40 Feet.
Sandstone and green marl	20 —
Red marl	10 —
	70

The stratification is very nearly horizontal.

The sandstone is obtained in large slabs and removed to Warwick, where it is used for tombstones and other purposes. It is whiter than the Warwick sandstone, and considerably harder, thinner-bedded, and closer grained. Small nodules of ironstone occasionally occur in it, and their great hardness gives much trouble to the stonemason. Ripple marks and septaria-like veins of sandstone are very abundant; and this locality is further distinguished by the occurrence of footsteps of animals, bivalve shells, and teeth of fishes, which will be described in the sequel.

The same beds are repeated at Rowington, where a deep cut on the canal exposes the following strata:

White sandstone and green marl	20 Feet.
Red marl	40 —
	60

The stratification horizontal.

At the foot of the hill south-east of Knowle, the same stratum of sandstone appears, and, though not exposed by quarries, may be seen in one of the locks on the canal. It is surmounted by red marl, which dips beneath lias, about a mile further north*.

* The outlier of lias, at Knowle, is about a mile and a half in length by half a mile broad. It was worked for limestone a few years ago at Waterfield Farm and Copt Heath, and the shafts of the workings still remain. The discovery of this outlier is due to Dr. Lloyd, of Leamington, to whom we are indebted for much valuable information on the geology of Warwickshire.

To the south-east of Warwick, the red marls are so denuded, that there is little hope of finding this band of sandstone clearly developed, though the sandy character of the ground at Radford, about two miles from the lias escarpment, seemed to us to indicate the range of the sandstone (see Section, Pl. XXVII., fig. 4.). The undulations and faults, near Warwick, by which the younger beds are reproduced as outliers on the north-west, are, therefore, very important for our present purpose. Having traced this peculiar sandstone through so wide an area, there was no difficulty in identifying it, when discovered near Knowle and in the adjacent hills, between that place and Warwick, as represented in Section, Pl. XXVII., fig. 4. Besides a precise mineralogical resemblance with the sandstones of Burge-hill, Ripple, and Inkberrow, the rock in Warwickshire contains the *same* peculiar little bivalve shell (*Posidonomya minuta*, Pl. XXVIII., fig. 4.) which occurs at the southern extremity of Worcestershire, and thus throughout a course of not less than forty miles, we are enabled to mark the position of this thin band of sandstone, and to distinguish it from other sandstones, which not only underlie it, but are separated from it, by a great thickness of marl.

Again, the exact geological position of this sandstone, which we consider to be the equivalent of the Keuper sandstone of Suabia and Alsace, is 200 or 300 feet below the lowest beds of the lias, a position, which coincides well with that of the principal mass of this sandstone in Wurtemberg, where one of the authors has examined it. In Germany, however, the Keuper formation contains several courses of sandstone and grit, but always subordinate to thick masses of marl. In England, we have one well-defined band only, which, occurring from 200 to 300 feet below the lias, is completely and distinctly separated from the great red sandstone of the central counties, by a vast thickness of red and green marls, which in certain tracts are saliferous. Independently of natural sections, the great thickness of the red marls, or the depth to which they extend beneath the Keuper sandstone, is established by the shafts and borings made at the saltworks of Stoke Prior, near Droitwich, where the gypseous marls with masses of rock salt, were penetrated to a depth of nearly 600 feet *without an indication of any bed of sandstone**.

Combining these facts with the sections exposed in the escarpments of Inkberrow, Knowle, and other places, it appears evident, that the Keuper of England (on the whole quite as largely developed as that of Germany) is, like the "Marnes Irisées" of France, a great marly formation, with one principal band

* See Dr. Hastings's paper in the Analyst. vol. ii. p. 359.

of sandstone subordinate to it, which sandstone is separated, by at least 600 feet of marls, from the great mass of the underlying new red sandstone.

Organic Remains of the Keuper. (Plate XXVIII.)

When our examination of this tract commenced, it was a prevalent belief, that as no fossils had ever been found in the red marl formation, so was it hopeless to look for them. We have now to announce the existence of fishes, shells, and the impressions of footsteps of probably a Batrachian animal. The locality, in which organic remains were first discovered in the Keuper sandstone, is at the Burge-hill quarries, before mentioned. Here, they are by no means plentiful, but after considerable search a long Ichthyodorulite was found*, (fig. 3.) with numerous casts of small bivalve shells (fig. 4.). This Ichthyodorulite manifestly belongs to an undescribed species of the genus *Hybodus*, (Agassiz,) and it is therefore exceedingly interesting in showing, that the same types of organization, which prevail in the lower lias, existed during the deposition of the upper part of the new red system. The dentated posterior margin of the spine is unfortunately wanting, but sufficient characters remain to warrant us in regarding it as a new species. It is remarkable for the straightness of the anterior margin, which hardly deviates one-eighth of an inch from a straight line. It appears to have been of a remarkably taper form, but from the loss of the hinder margin the diameter from front to back cannot be determined. The transverse diameter at the larger end is about three-eighths of an inch, and the total length is five inches. The longitudinal *costæ* are smooth, rounded, regular, and closely packed; at the larger end six of them cover a quarter of an inch (*i.e.* their diameter is one twenty-fourth of an inch). We propose to name this species *Hybodus keuperinus*.

The bivalve shells, (Plate XXVIII., fig. 4.) appear to be the *Posidonomya minuta* of Bronn (*Lethæa Geognostica*, page 164, Pl. XI., fig. 22.), or the *Posidonia minuta* of Goldfuss (*Petrefacten*, Pl. CXIII., fig. 5.) and of Zieten (*Versteinerungen Wirttembergs*, Pl. LIV., fig. 5.)†.

In Germany, this shell is stated to pervade the new red system from the "Keuper" to the "Bunter sandstein" inclusive, but in this country, it appears peculiar to that band of sandstone, which we have proved by stratigraphical evidence to represent the upper formation. It is indeed a very characteristic shell, for,

* By Mr. Strickland.

† Bronn has changed the generic name to *Posidonomya*, the term *Posidonia* being pre-occupied in botany. Capt Portlock has lately detected this shell in the new red sandstone of Roan Hill, near Dungannon, Ireland.

as previously stated, we have detected it at Burge-hill and Inkberrow, in Worcestershire, and at Shrewley Common, in Warwickshire, where it is very abundant in some of the sandstone beds.

Batrachian.—Our proofs of the existence of probably a Batrachian in this rock, are similar to those which have been held sufficient to establish the claims of the sandstones of other countries to a similar distinction, *viz.* the impressions of the feet of animals. The slabs which we lay before the Society will, we trust, bear out this inference. (Fig. 1.) We found these interesting relics in the sandstone of Shrewley Common. They afford the same proofs as those which were insisted on in the case of the footsteps of tortoises in Dumfries-shire, *viz.* the same inverted position of the claws—similar raised portions of sandstone behind each impression, caused by the progressive movement of the animal—and similar indentations proving occasional halts in the march of the animal; in short, all the *indicia* by which the Rev. Dr. Duncan was first led to refer the impressions in the red sandstone of Dumfries-shire to the footsteps of animals, and by which Dr. Buckland sustained and established those views. The Warwickshire impressions are further distinguished by a depressed groove, running intermediate between the footsteps, and apparently caused by the tail of the animal dragging in the soft sand. Plate XXVIII., fig. 1, represents a large slab, now in the Warwick Museum, the counterpart of that which we have presented to the Society. These footsteps, which are given of their natural size in fig. 2, bear some resemblance to one of the Hildburghausen species figured in Buckland's "Bridgewater Treatise," Plate XXVI^{m}; and supposed by Mr. Owen, Mr. Broderip, and other zoologists who have examined them, to belong to some genus of crocodilean saurian. Greater accuracy of definition cannot at present be attained; but perhaps, when the science of comparative ichnology shall be more advanced, the nature of the animal, which has left us these faint traces of its existence, may be ascertained with greater precision.

Teeth of Fishes.—Two small teeth of squaloid fishes were found at Shrewley.

§ 2. *New Red Sandstone* (*For. Syn., "Bunter Sandstein" and "Grès Bigarré."*).

The red sandstone of Gloucestershire (as described on former occasions), is comparatively of small dimensions; but, as the formation advances to the north of Worcester, it expands, and massive strata of sandstone rise from beneath the thick cover of marls above described. The uppermost beds of this great sandstone formation are distinctly exhibited, at various places, between

Ombersley and Bell Broughton. At Ombersley, and the adjoining hamlet of Hadley (Plate XXVII., fig. 5.), these beds have been much quarried; and they afford a very beautiful lightish-coloured, fine-grained, slightly micaceous, quartzose sandstone, sometimes tinged with slight shades of pink and green; but a delicate olive colour prevails. At Hadley, the quarries expose from 30 to 40 feet of sandstone, covered by red marl. The sandstone is of greenish white colours, tinged, in parts, with purplish and reddish hues, and it is somewhat micaceous; the upper portion, or that nearest the marls, being a breccia of marl and sandstone. About 8 to 10 feet below the surface, carbonaceous laminæ are very abundant; and on flaking off the beds, their surfaces are found to be covered by numerous impressions of plants, nearly the whole of which have passed into a black powdery charcoal, which readily disintegrates on extraction. Hence, it is very difficult to preserve these fossils with all the freshness of form, which they exhibit when first disinterred; and when the jet-black colour forms a striking contrast to the light buff-coloured matrix. When the black, incoherent matter has fallen out, the impression of the matrix is usually marked by ferruginous colours. The large slabs, which we procured for the Society from this locality, have been examined by Professor Lindley, who thus expresses himself concerning their vegetable contents:—

"The only plant among the specimens, that has been published, is the *Echinostachys*, of which slight traces are visible (Plate XXVIII., fig. 11.). I presume they all belong to the same species; but at all events, one of them *is identical* with that published by Adolphe Brongniart, from the *Grès bigarré* (*E. oblongus*). The remainder of the impressions consist of many narrow, monocotyledonous leaves, resembling those of *grasses*, a portion of a *flabelliform palm-leaf*, some large moulds of stems of a doubtful character, a longitudinal section of a portion of a *dicotyledonous stem* with the bark on, a considerable portion of a broad leaf of some monocotyledon, and a great multitude of fragments wholly indeterminable. I can detect no trace of a Voltzia, unless a very imperfect stain upon one of the smaller slabs should be of that nature; the genera Æthophyllum and Paleoxyris are equally absent; Convallarites may be present in the form of some of the broken leaves, but it cannot be identified."

Owing to a line of dislocation, which runs along the Doverdale valley, the sandstone of Hadley is thrown to the west, and is partly covered by marl; but farther west, it rises with a gentle easterly dip; and in that position forms the low ridge, at the southern end of which is the village of Ombersley*. By pursuing a transverse section from this little ridge to the Severn, we pass through an unbroken, descending series of sandstones, in the following order. (See Plate XXVII., Section, fig. 5.)

* The quarries from which the pretty church of Ombersley was built, are about half a mile south of the village, but they are now abandoned. This is the point at which the rock first emerges from beneath the marl; and hence it is overlaid by much rubbish.

a. Beds of the Keuper or red marl, forming the crest of the Hadley and Ombersley ridge.

b. Thin-bedded, red sandstone.

c. Sandstone of a whitish and yellow colour, with plants similar to those of Hadley, 10 feet below its surface.

d. Thick masses of deep red sandstone. They rise up to the west, and cap the hills on the left bank of the Severn above Holt Bridge. They are underlaid by wayboards of sandy marl.

e. Alternating thin bands of coarse, concretionary, or rather fragmentary marlstone,—gritty small quartzose conglomerate, and soft, thick-bedded, dull red sandstone, the latter much predominating;—the whole dipping E.S.E. about 12°. The right bank of the river, at Holt Bridge, offers magnificent sections of the massive red sandstone, some quarries exposing faces of 60 feet and upwards.

This transverse section from Hadley and Ombersley to the river Severn, completely establishes the fact, that the light-coloured *sandstone, with plants, is inseparable from the great mass of red sandstone, and lies beneath the whole of the Keuper marls,* by a large portion of which, it is entirely separated from the true Keuper sandstone.

In following the Ombersley ridge upon its strike to Elmley Lovett, the same light-coloured sandstone is found, at intervals, for five or six miles, and is largely quarried at the latter place. Here, indeed, the prevalent tint of the rock is *red,* and the plants are again found in some quantity, generally in layers, which separate the principal masses of sandstone. The line of dislocation which passes by these quarries, will be noticed hereafter. The tract to the east of this ridge is covered by red, saliferous marls, extending by Droitwich to Stoke Prior. But at Bromsgrove, the peculiar sandstone of which we are speaking, rises from beneath the marls, and offers, on the high road from Droitwich, a most instructive section, which confirms, in every respect, the transverse section from Ombersley to the Severn, and proves the light-coloured rock to be an integral part of the great red sandstone formation.

Descending section of Breakback Hill, one mile S.W. of Bromsgrove:

Red marls crowning the hill.

a. Ledge of darkish red sandstone, consisting of
Thin-bedded earthy sandstone, alternating with marls, and whitish, thick-bedded, soft sandstone. Top beds partially brecciated like those of Ombersley, and inlaid with blotches of greenish marl. It contains fragments of plants and carbonized wood.

b. Thick-bedded, greenish white sandstone, full of plants.

c. Deep red coloured, solid, massive sandstone, scarcely micaceous, without wayboards; 40 feet are exposed in one quarry. Patches of marl, here and there, inosculate in the form of wedges or irregular concretions.

d. Light yellowish and brownish sandstone, with wedge-shaped masses of grit and marly calcareous breccia, occasionally cavernous, with traces of plants.

e. Red sandstone, slightly green in some parts.

These last-mentioned beds lie near the turnpike-gate, west of the town of Bromsgrove, the whole mass dipping westerly. They are succeeded, on the opposite side of the valley in which the town stands, by distinct courses of deep, red, soft sandstone, which in their turn are underlaid by strata, containing irregular concretions of impure limestone or cornstone. The further consideration of these lower beds, in Worcestershire, would carry us beyond the limits of this memoir; and as they have been already described, at some length, by one of the authors, and proved to be the equivalents of the Dolomitic Conglomerate and Lower New Red Sandstone,* and that the latter passes down conformably into the coal-measures, they are now merely cited to corroborate the inference, that the overlying red sandstone of Bromsgrove, including the light-coloured rock, with plants, constitutes the true equivalent of the Bunter Sandstein†. (Plate XXVII., fig. 5.)

Sandstone of Warwick.

We now proceed to show, that the sandstone of Warwick occupies the same geological position as that of Ombersley and Bromsgrove. In approaching Warwick from the west or south-west, this peculiar rock rises suddenly from beneath the red marl. It extends for several miles to the north-east, and is quarried at Warwick, Guy's Cliff, Leek Wootton, Blakedon Hill, Leamington, Bubenhall, and other places. Its strike appears to be from north-east to south-west; while its abrupt termination at Warwick may perhaps be due to a fault ranging in a northerly direction to the west of Kenilworth. It is probable that the upcast which has thus raised the sandstone above the marls on the west, has given the more or less dome-shaped structure to the hill on which

* See The Silurian System, p. 46, *et seq.*

† Passing over these lower rocks, and also those of much higher antiquity, which constitute the Lickey, we again meet with a fine section of whitish sandstone rock at the "Sandhills" near Alvechurch, the dip being reversed, to the N.N.W. The section of these quarries consists, in descending order, of

a. Red loam and marl..... 6 to 8 feet.

b. Thin, flag-like sandstone and marl alternating ..... 10 to 12

c. Solid, whitish sandstone, of a delicate green tinge, void of wayboards, soft under the hammer, and working into any form. Lines of bedding partially indicated by flakes of dark mica, so that when cut and smoothed, the undulations of the dark-coloured material appear through the light-coloured ground; thus producing the appearance so well known in the *Cipollino* marble. In other parts, the mass is freckled with small dark spots (manganese?), which, when the stone is rubbed down, give it a warm brown tinge. We could detect no plants or organic remains in this beautiful sandstone. It is perhaps, therefore, not precisely of the same age as that of Bromesgrove and Ombersley, but a repetition of analogous strata rather lower in the series.

Warwick stands. On the south, however, the sandstone rises quite conformably from beneath the red marl; while, on the other side, the stratification, as far as the irregular bedding allows it to be traced, appears, in some places, to dip towards the north-west*. (See Plate XXVII., fig. 4.)

At Leamington, the same sandstone rises very gradually from beneath the red marl on the south. The uppermost beds consist of very soft sandstone and white sand, with alternations of marl. The following section was lately exposed in cutting a large drain on the south side of the Leam :—

a.	Gravel with flints	6 to 8 feet.
b.	Light-coloured sand with an irregularly denuded surface, containing concretionary masses of sandstone	3 to 5
c.	Red marl	4

The concretionary masses in the sand contain numerous fragments of bone, in a better state of preservation than is usual in the Warwick sandstone. They appear, however, to have undergone much attrition; and it is rare to find any traces of their original form. A small tooth of a fish, probably that of a shark, was also found in these sandy concretions.

Below these rubbly beds, the sandstone assumes a degree of compactness, which adapts it for masonry; and many houses in the new town of Leamington, are built with the stone which has been extracted from their cellars. Indeed, in beauty of tint, facility of working, and durability, the light-coloured sandstone of Warwickshire and Worcestershire, like that of Grinshill, near Shrewsbury, with which we shall presently compare it, is probably surpassed by no other rock in the British isles.

To the north of Leamington, the same variety of the red sandstone is quarried at Blakedon Hill, where fragments of bones have also occurred in it. At the northern foot of this hill, the subjacent sandstone, of a deep red tint, commences; but the junction of the two rocks is not exposed.

The quarry, which has been most productive in the remains of *Vertebrata*,

* About one mile north of Warwick, and half a mile north of the canal, is a singular knoll of sandstone, partly removed by quarrying, which must be very near the line of this fault; for at the canal bridge, on the south-west, a section of red marl is exposed, and no traces of the subjacent sandstone are visible. This fault, as it passes Kenilworth, is much obscured by the abundance of gravel; but its presence is proved by the fact, that there is no intervention of the buff-coloured or Warwick sandstone, between the red sandstone of Kenilworth and the red marl, which appears to abut against it on the west. To the south-east of Warwick, the hill of red marl called Highdown Hill, with a strip of lias at its eastern base, not improbably indicates the continuation of the fault, above described.

is at Coton End, on the south-east side of Warwick, where the following section is exposed:—

a.	Soft, white sandstone and thin beds of marl	8 feet.
b.	Whitish sandstone, thick-bedded	12
c.	Very soft sandstone, coloured brown by manganese, called "Dirt-bed" by the workmen	1
d.	Hard sandstone, called "Rag," about	2
		23

The dip about 3° to the S.

The bones are principally found in the so-called "Dirt-bed." They are in the same rolled and fragmentary condition as at Leamington, but in a state of much greater decomposition. When first taken from the quarry, they resemble stiff jelly, with singular hues of blue and red. It is necessary to remove them with great care from the quarry, and when dry, to saturate them with a solution of gum arabic, as the best means of preserving them. The only specimens which exhibit any distinct zoological characters, are some teeth obtained by Dr. Lloyd, to whose kindness we are indebted for the figures given of them in Plate XXVIII., figs. 6, 7, 8.

The light-coloured sandstone extends from Warwick, by Guy's Cliff, to Wooton Grange; beyond which it is succeeded by the underlying redder sandstone of Kenilworth. In a quarry in the grounds at Guy's Cliff, is the following section:—

Sandstone and beds of marl	8 feet.
Solid sandstone, whitish or grey, occasionally of a reddish tint	12
Red, micaceous marl, with wedges of sandstone	8
Solid, light-coloured, reddish tinted sandstone, about	20
	48

The bedding very irregular. Ripple marks occur on some of the beds.

We have now to speak of the redder sandstone which underlies the light-coloured strata. The upper part of this red rock consists of flaggy beds, with marly wayboards. In a quarry, south-east of Ashow, on the left bank of the Avon, is the following section:—

a.	Thin, flaggy beds of red sandstone	6 feet.
b.	Thick-bedded red sandstone	8

Calcareous matter pervades the thin beds *a*, in concretionary patches; and where that is the case, the sandstone is intensely hard.

One of the best sections of the red sandstone is in a quarry on the north-west of Kenilworth Castle :—

a.	Laminated, marly red sandstone	5 feet.
b.	Thick-bedded, reddish brown sandstone, sometimes discoloured by manganese, with occasional fragments of red marl, and a few rolled pebbles of altered sandstone and porphyry	20
		25

The bedding irregular. The general dip about 5° S.E.

It is needless to give further details respecting this great red sandstone deposit, for its general features are very uniform. We therefore proceed to make a few concluding observations.

The section fig. 4, proves that the light-coloured sandstone of Warwick agrees completely with the rocks of Ombersley and Bromsgrove, (fig. 5.) in rising from beneath the marls, and in passing downwards into solid red sandstone. Although this rock has been recently described by Dr. Buckland, it is essential to our purpose to state, that, from geological and other evidences, we consider that it cannot be, as he conceives, the equivalent of the German Keuper. The true position of that rock is, fortunately, indicated in natural sections near Warwick, as well as in many parts of Worcestershire, where it is demonstrated that the *thin-bedded* sandstone, or true Keuper, is separated from the *thick-bedded* sandstone of Ombersley, Bromsgrove, and Warwick, by a vast thickness of red and green marl. Obedient, however, to geological principles, based on zoological evidences, we should not pretend to set up the classification here suggested, in opposition to the views of so distinguished a geologist as Dr. Buckland, if founded only on the relative geological position of these rocks. On the contrary, if it could have been shown, that the fossils which we have now pointed out as characterizing the upper sandstone, occurred also in the lower,—that the plants in the lower sandstone were similar to the well-known plants of the German *Keuper*,—and that the fragments of Saurians found in the sandstones of Guy's Cliff and Warwick really belonged to the *species* peculiar to the Keuper,—then, indeed, we should willingly allow that the lower sandstone *also* must be grouped with that formation. Seeing, however, that the animal remains of the one sandstone are, as far as we can judge, entirely different from those of the other, and that the plants, so abundant in the lower rock, have none of the characters of the Flora of the Keuper, but, on the contrary, contain one remarkable plant, the *Echinostachys*, a genus considered by Adolphe Brongniart as peculiarly characteristic of the *Grès bigarré*,—we are compelled to adhere to our opinion, and to contend that the peculiar sandstone of Burge-hill, Ripple, Inkberrow, Alcester, Shrewley Com-

mon, &c., which we have been the first to describe, is the true equivalent of the *Keuper Sandstein*; and that the sandstone of Ombersley, Bromsgrove, and Warwick, is not the *Keuper*, but a portion of the *Bunter Sandstein*. In respect to the Saurian of Guy's Cliff, which we have had no opportunity of examining, it is sufficient to state, that Dr. Buckland himself does not contend that it is either of the species of the *Phytosaurus* (*Jäger*) of the German Keuper; and he hesitates even to refer it to that genus. Now the mere existence of a Saurian in the Warwick sandstone proves nothing; for geologists are well aware, that various species of the family occur in all the formations, from the lias down to the magnesian limestone inclusive. Indeed, as these animals are not unfrequent in the Bunter Sandstein of Germany, we cannot avoid suspecting that the animal remains of Guy's Cliff may, if ever accurately determined, be assigned to some of those species, mentioned by M. Voltz and others, as occurring in the Bunter Sandstein, or German deposits, which, from the other proofs adduced, we consider to be of the same age.

In concluding this sketch of the structure and contents of the two upper formations of the New Red System, in the central counties of England, we may observe, that in Shropshire and the adjacent parts of Staffordshire, where these deposits have been described at length by one of the authors, the upper marls, or Keuper, have been so much denuded, particularly near their junction with the lias, that the peculiar band of Keuper sandstein which we have found persistent in Gloucestershire, Worcestershire, and Warwickshire, has not yet been met with. But, rising from beneath the whole of the marls, and apparently separating them from the underlying massive sandstones, there does exist a thin course of impure limestone, which, it is presumed, may represent the *Muschelkalk*, and of which an account is given in Mr. Murchison's work*. If this should really prove to be the equivalent of the Muschelkalk, the age of the formation which underlies it, will be still more clearly established; for the sandstones of Cheshire and Shropshire, which there rise from beneath the saliferous marls, as in Worcestershire and Warwickshire, correspond in mineral structure with those which we have been describing, particularly in containing, near their upper limits, courses of a stratum (sometimes 70 to 80 feet thick) of whitish or light-coloured sandstone, of which the celebrated quarries of Grinshill, near Shrewsbury, and the picturesque rocks of Hawkstone, are good examples†. These rocks are indeed identical with the sand-

* The Silurian System, p. 36.

† At Grinshill, eight miles north of Shrewsbury, where the rock is identical with the best building-stone of Leamington and Warwick, the mass of whitish coloured sandstone (80 feet thick) is exposed, between a cap of red marly sandstone and a deep red sandstone of vast thickness, on

stone of Ombersley, Bromsgrove and Warwick; and like those we have here described, they pass into, and are inseparable from, the great mass of the New Red Sandstone of England, which, from geological and zoological proofs, we consider to be the equivalent of the Bunter Sandstein.

In thus identifying the red and green marls, and an included band of sandstone with the Keuper, and separating this marnose formation from the underlying sandstones, we have the direct authority and example of the best French geologists; for M. Elie de Beaumont, in a memoir on the Vosges, has shown that the formation of *Marnes Irisées*, which he places on a parallel with our English red marl, is the true representative of the Keuper; and in the south-western parts of France, M. Dufrénoy has shown us, that these marls and the underlying sandstones, are brought together precisely in the same manner as in England, the Muschelkalk, or subdividing limestone, having thinned out*.

In a subsequent memoir, we may offer some explanation of the lines of dislocation, by which these deposits have been affected.

POSTSCRIPT.

Dr. Buckland has described in the Geol. Proc. v. ii. p. 439, the silicified stems of trees, which occur at Allesley near Coventry, but has not determined the age of the rock in which they are imbedded. Having visited that spot, we have no doubt that these trees occur in that part of the series, which we have shown to be the equivalent of the Bunter Sandstein. The red sandstone of Kenilworth may be traced without interruption from that place to Coventry and Allesley, where it is interstratified with beds of quartzose and trappean conglomerate, which are identical with those of North Worcestershire, Staffordshire, &c. (See Mr. Murchison on The Silurian System, p. 42.) The fossil trees of Allesley are found in a stratum of this conglomerate, containing manganese, and lying between strata of ordinary red sandstone.

The same red sandstone occurs in thick beds at a quarry, lately opened, about three quarters of a mile N.W. of Coventry. It differs in no respect

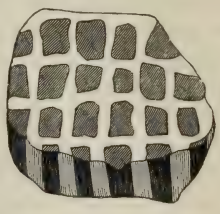
which it rests; thus perfectly resembling the section at Bromsgrove. The Hawkstone Hills are chiefly composed of the same light-coloured variety of the Red Sandstone. It is indeed remarkable that a mere lithological distinction of colour should be so very persistent.

* See Dufrénoy and Elie de Beaumont *Mémoires pour servir à une déscription géologique de la France*, vol. i. p. 313, *et seq.*

from the sandstone of Kenilworth, and the only remarkable circumstance connected with this quarry, is the discovery of a fossil jaw, represented at Plate XXVIII., fig. 5. The teeth of this jaw are very irregular both in form and position, and appear to have lost much of their destructive character by trituration. The teeth are not inserted in alveoli, but are united with the maxillary bone like the teeth of fishes.

This specimen, the only example known of an animal relic in this part of the New Red Sandstone of central England, is deposited in the Warwick Museum.

At the railway station near Coventry, the cuttings have laid bare the upper or light-coloured beds of variegated sandstone, spotted with manganese, dipping to the E.S.E., and covered by the red marl or Keuper, which, on the line to London, is seen to graduate into and pass under the lias. In following the rail-road from Coventry towards Birmingham, the underlying or deep red sandstone is traversed; and in the adjoining hill of Meriden, it is again capped by the same light-coloured rock as at Coventry. The red sandstone continues as far as Berkswell, where it is succeeded by the upper marls of the Knowle basin, which extend to within a mile of Birmingham. At Berkswell a singular variety of this sandstone occurs, exhibiting the appearance of a pavement of bricks, 2 or 3 inches square, separated by bands of a whitish cement. The stone splits into thin flags, and the division in the colours extends through each layer. No change of texture is visible in the white bands from the red portions which they inclose; but along the centre of each is a fine raised line, apparently due to a cast in an extremely narrow crack. The following woodcut represents a fragment of this stone.



A similar sandstone is stated by Dr. Macculloch to occur in the coal-measures of Arran. Description of the Western Islands, vol. ii. p. 374.

XXVII.—*A Description of various Fossil Remains of three distinct Saurian Animals, recently discovered in the Magnesian Conglomerate near Bristol.*

By HENRY RILEY, M.D., and Mr. SAMUEL STUTCHBURY, A.L.S.

Communicated by CHARLES LYELL, Esq., P.G.S.

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THE fossil remains, described in this paper, were found in quarrying the brecciated beds, which rest upon the highly-inclined carboniferous limestone at Redland, the south-eastern extremity of Durdham Downs, near Bristol. The breccia at this spot is not more than twenty feet thick, and is composed of angular or slightly worn fragments of mountain limestone, cemented by a red or yellow magnesian paste.* It occurs in patches over the whole of the Downs, filling up the hollows and irregularities in the limestone; and it is exhibited in the parishes of Westbury and Henbury, in Gloucestershire, and St. George's in Somersetshire; it forms likewise the well-known precipitous cliffs and interesting sections at Hungroad, on the Avon; and is exhibited in the valley of the Trim, as well as at other places. It is desirable to repeat the observation of Dr. Buckland and Mr. Conybeare, that wherever the breccia occurs in the neighbourhood of Bristol, it is principally composed of the debris of the rocks on which it rests.

The whole of the bones were evidently dislocated before they were entombed, as several of the specimens were found in actual contact with the mountain limestone, while others were dispersed throughout the breccia: many of the bones were also clearly fractured before they were enclosed.

This deposit has been considered the representative of the lower divisions of the new red sandstone series of Yorkshire and the adjacent counties;

* For descriptions of the Dolomitic conglomerate near Bristol, see Dr. Bright's Memoir, Geological Transactions, 1st Series, vol. iv. p. 193; Mr. Warburton's, p. 205; Dr. Gilby's, p. 210; and the Memoir of Dr. Buckland and Mr. Conybeare, on the S.W. Coal District, 2nd Series, vol. i. p. 291, *et seq.*

and to be in the place of a great part of the Thuringerwald system*. It is therefore hoped, that the discovery of the Saurian bones described in this paper, will materially assist in connecting the dolomitic breccia of Bristol with the beds which contain the fossil Monitor of Thuringia.

We now proceed to describe the bones which we have obtained.

Plate XXIX., fig. 1. natural size; fig. 2. magnified three times.

Fig. 1. A portion of the right ramus of a lower jaw fractured into three pieces, and containing twenty-one teeth.

Its outer surface is completely exposed, but the inner is imbedded in the rock, and cannot be observed. The length of the specimen is $3\frac{1}{4}$ inches, and at an inch and a half from the anterior extremity, where the teeth are perfect, the depth from the apices to the inferior edge of the jaw is $\frac{8}{10}$ths of an inch. The external surface is convex vertically, and slightly curved inwards, antero-posteriorly, both below and above.

The fragment consists of a dental and portions of the sur-angular or coronoid bones. Of the dental bone, the greater part remains; but of the other there are imperfect portions only. Posteriorly and internally may be traced a white line separated by the matrix, and parallel with the preceding: it is probably the remains of the opercular bone.

Seven foramina are arranged in a line for the inferior maxillary nerves and vessels, and are contained in a groove, shallow anteriorly, but increasing in depth posteriorly; at which part the external bone is broken away, so as to expose the sub-maxillary canal filled with spar of a red colour. The upper edge, forming the alveolar groove of the dental bone, contains the teeth already mentioned; and, from its transverse fractures, it is evident, that this groove is formed by two ridges, the inner being as high, or nearly as high, as the outer ridge, so that the teeth are inclosed in the dental bone to nearly one half of their whole length. The spaces between the teeth in the groove, are filled up with spar; and at the posterior part only can we observe any transverse septa, so as to constitute distinct alveoli.

There were apparently twenty-one teeth in the ramus; and from their decreasing in size towards the back of the jaw, it is more than probable, that that was the complete number.

The teeth are acutely pointed, fig. 2. and flattened, and the anterior edge is curved backwards, and serrated; the posterior edge is also slightly curved, and strongly serrated, the serratures being directed towards the apex of

* See Prof. Sedgwick's Memoir on the Magnesian Limestone, Geological Transactions, 2nd Series, vol. iii. p. 122.

the tooth,—the outline of each tooth thus somewhat resembling a surgeon's abscess lancet, with an elevation extending on the outer side, down the middle, from the point to the crown. These characters, to be well seen, require a magnifying glass. The middle teeth are the largest, measuring not less than a quarter of an inch above the socket: they all possess a conical hollow, filled up by spar, of the same red colour as that already mentioned. No germs of new teeth have yet been discovered; but this is probably owing to the outer surface only of the jaw being exposed.

Since writing the above, we have been favoured with a sight of a small portion of a jaw (Fig. 3.), in which the alveolary septa and a young tooth are well exhibited: this specimen is in the possession of the Rev. David Williams, of Bleadon.

From the foregoing characters it is clear, that the remains in question are those of a Saurian. In determining the zoological position of the animal, it is evident, First, That the distinct alveoli of the jaw separate it from the great genus Lacerta of Linnæus, as reformed by the Baron Cuvier, by rejecting the Crocodiles and the Salamanders.

Secondly, That the presence of distinct alveoli, is a character by which the animal approaches in structure to the Crocodiles; but from the lancet form and crenations upon the teeth, although there is one exception to the latter character, we may conclude that it did not belong to the Crocodiles.

Thirdly, It cannot appertain to those Lizards whose alveolar inner edge is either wanting or much less elevated than the outer one; since, in the specimen, the inner edge is of equal height with the outer.

Fourthly, The same characters, viz. an elevated inner alveolary edge, and distinct alveoli, and the formation of the new tooth in the same cell with the old one, into whose hollow it penetrates, most clearly distinguish it from the Monitors.

Fifthly, That the number of the teeth, twenty-one, is much greater than in the Monitors, which rarely have more than twelve on a side, and irregular in size and form, while in the fossil animal, they are comparatively regular in both of these points.

Sixthly, Although some Monitors have flattened and sharp teeth, with their edges finely serrated, a character possessed by our fossil, yet as in the recent animal the cavities, when their growth is terminated, are filled up and become solid, but in the teeth of the extinct Saurian remain permanently hollow, another point of difference is established; thus we consider these characters sufficient to exclude the animal from the genus Monitor.

Seventhly, In the number of the teeth, this jaw much resembles the Iguanas and Scinks; but the distinct alveoli, and the inner alveolar ridge, and the different forms of the summits and serratures in the species here described, are at once sufficient to distinguish it from them.

Eighthly, In form, position, interior cavity, and developement, they have a nearer resemblance to those of Saurodon of Hay *; but the *Saurodon Leanus* has the edge of the teeth smooth.

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* Description of a fragment of the head of a new fossil animal discovered in a marl pit, near Morristown, New Jersey, by Isaac Hay, M.D. Transactions of the American Philosophical Society, New Series, vol. iii. p. 471., Plate XVI., 1830. See also the Sketches A. B., Plate XXIX., accompanying this memoir.

Another distinction in the Saurodon is in the different length of the edges, one being longer than the other.

Under these circumstances we consider our animal to be a new genus, and shall found it upon its being a Lizard with alveoli in its jaws.

We propose to designate the animal generically, from the characters of the jaw and teeth combined, by the name of Thecodontosaurus.

We have also two separate teeth, which differ from the preceding and from each other. Fig. 5, a single tooth $\frac{7}{10}$ths of an inch long and $\frac{5}{10}$ths broad, *carinated* ? laterally and finely serrated at right angles to the axis ; this tooth approaches more nearly in form and serratures to the upper portion of the tooth of a Megalosaurus. Fig. 4. The portion of this tooth which has been preserved, is about $\frac{5}{10}$ths of an inch in length, and $\frac{8}{10}$ths in breadth : the edge is finely carinated, as in fig. 5. These teeth differ so much from all those of Saurians with which we are acquainted, and so greatly from each other, that we are inclined to attribute them to two new animals. For the present we propose to name the genus *Paleosaurus*, and the species, from the form of the teeth, may be called *P. Cylindrodon* and *P. Platyodon*, Figs. 4 and 5.

Vertebræ.—Plate XXIX., fig. 6, 7, and 8, natural size.

The few vertebræ which have occurred, are so much mutilated, that we have great difficulty in determining even the region of the columns, to which they belonged.

With one exception, we are not possessed of a specimen having the body or annular portion in its complete form ; whilst with regard to their processes, we have not a single instance of one, even in a tolerable state of preservation.

The specific and generic characters must, therefore, with our present means, be still more difficult of attainment.

Wherever we are able to inspect the bodies of the vertebræ, we observe that they are concave at each end.

In the best preserved specimens, the centre of each body is so much diminished in its transverse and vertical diameters (Fig. 6.) as to be reduced inferiorly and laterally to one half of the size of either end.

In one instance, we can distinctly trace a suture connecting the annular part or body with the process (Fig. 6.). In the same specimen, we have a mould of the vertebral or spinal canal composed of the magnesian matrix ; and it shows a very peculiar form in the upper portion of the annular element, constituting the inferior boundary of the canal. The body of the vertebra is hollowed out by a deep and narrow depression on its upper surface, so that the inferior boundary of the vertebral canal would not be on one level plane,

as in other animals, but would present a succession of narrow and deep depressions corresponding to the body of each vertebra (Figs. 6. and 7.). The inferior surface in the vertebra (Fig. 6.) presents a concavity to the depth of $\frac{3}{10}$ths of an inch.

In this way, the vertical diameter of the canal would, at the middle of each vertebra, be one-half more than at either of its points of junction with the next vertebræ. Traces of the same peculiarity are visible in two other specimens.

The leading characters of these vertebræ are, 1st, their double concave system; 2nd, the hour-glass form of the annular portion; 3rd, the sutures connecting the bodies with their processes; and 4th, the peculiar form of the vertebral canal.

With regard to the first character, it separates our animal remains from all known recent genera; while the third character separates it from the recent Saurians excepting the Crocodile.

Although the concavo-convex system pervades nearly all the recent Crocodiles and Lizards, it by no means applies with regard to the determination of their extinct genera. Thus the Crocodiles of Honfleur, of Caen, of Tilgate, have a slight concavity of the articulating surface of each body. The Megalosaurus has the same peculiarity. The whole of the Enaliosaurians are more or less doubly concave; in fact, nearly all the more ancient extinct Saurians are thus characterized.

We know of no other remains having such deep concavities as those in question, except the Ichthyosaurus; but our specimens evidently do not belong to that genus from their other proportions, which separate them in the most distinct manner.

Thus their antero-posterior diameter is double in proportion to that of the Ichthyosaurus.

The hour-glass form of the bodies, the deep concavities, and the sutures, would likewise exclude them from the Monitors.

These characters bring them nearer to the Crocodiles of Honfleur and the Megalosaurus, than to any other remains with which we are acquainted; and with regard to the latter, the difference in size is certainly a great objection; but this circumstance is not sufficient to invalidate our opinion, since there are instances of as great differences where analogies as close have existed.

The peculiar form of the canals of some of our specimens of vertebræ, is so novel to us, that we shall not at present attempt to found any conclusion upon it, but await the chance of future opportunities of studying its nature.

Chevron Bone.—Plate XXIV., fig. 9, natural size. This bone, which is very nearly perfect, we consider to be a chevron bone.

Ribs.—Plate XXIX., fig. 10, natural size.

We have ribs of two types,—one flat, the other round. We have not ascertained the forms of either of the extremities of the flat ribs. Fig. 10. is a rounded rib, and has a double head, with a deep intercostal groove.

The double head would approach it to the anterior thoracic ribs of the Crocodiles; but the rounded form and intercostal groove would connect it more nearly with the Lizards. We are disposed to consider these rounded ribs as belonging to the jaw already described.

Clavicle.

We are inclined to consider an imperfect bone as a clavicle; it approaches in form the clavicles of *Iguanas*.

Coracoid.—Plate XXIV., fig. 11.

We have two fragments, which are undoubtedly portions of coracoids.

The convex or sternal edge is completely destroyed, but the concave edge is more perfect, and it is divided into two smaller curvatures by a long process, by which it is articulated with the cartilaginous arch connecting it with the T-shaped or ento-sternal element of the sternum; the two other processes arising from this edge can scarcely be traced.

This coracoid, although so much injured, is nevertheless sufficiently preserved to show that it belongs to a Saurian, having a more complicated shoulder than a Crocodile; but it is not perfect enough to enable us to determine more than that it belonged to an animal allied to the numerous family of the Lizards.

Humerus.—Plate XXX., fig. 1. 1 *a*, reduced to one half the natural size.

This specimen we consider to be a right humerus, showing the bone in a pretty perfect state of preservation.

It is remarkable from one of its sides being nearly straight, whereas the other is concave.

The articulating extremities expand to nearly three times the diameter of the centre of the bone.

It is not unlike the humerus of a Monitor, but it resembles more that of a Crocodile.

Radius.—Plate XXX., fig. 2. Half the natural size.

In the middle this bone is straight, cylindrical, increasing in size at each extremity, particularly at the superior one, where we notice a deep groove, which we consider the articulation for the ulna; the inferior articular surface is so much injured that we cannot make out any of its characters.

The following are the dimensions of the bone:—

Length, 7 inches;
Breadth of the superior extremity, 2 inches;
At its inferior extremity, $1\frac{1}{4}$ inches.

From the above characters we consider ourselves justified in considering it a radius.

Femurs.—Plate XXX., fig. 3, 4, and 4a, reduced to one half.

Two femurs, in a tolerable state of perfection, have fortunately been found; one, of the right side, exhibiting nearly the whole of the bone, the inferior condyles only wanting. Fig. 3.

The other is of the left side, and exhibits the condyles, but is very imperfect at the superior extremity. Fig. 4, 4a.

The first mentioned (Plate XXX., fig. 3.) measures 10 inches in length; from the head to the middle of the trochanter, 3 in. $\frac{6}{10}$ths; from the trochanter to the inferior condyle, 5 in. $\frac{7}{10}$ths.

In the left femur the transverse diameter of the condyles is 2 in. $\frac{3}{10}$ths, the centre of the cylinder 1 inch.

They are curved in two directions upon the axis, giving them somewhat a twisted form, or the shape of a long *ſ* antero-posteriorly.

The trochanter is well preserved, wedge-shaped, and of considerable size, as may be seen by reference to the figures.

The articular head is flattened at the space between the trochanter; and the articular extremity is more curved than any other part of the bone; the centre is nearly round, but a slight elevation or ridge exists on its posterior surface, in the situation of the linea aspera of the human femur.

The condyles are flattened, the outer one being the larger; there is a deep depression between them posteriorly, and a very slight one anteriorly.

On an attentive comparison of these femurs with those of the Crocodile and Megalosaurus we again recognise a resemblance.

A comparison with the femurs of the Monitors evidently shows that our animal cannot have belonged to that family.

The femurs of the Monitor are much less curved, being nearly straight, and the trochanter is much nearer the articular extremity, characters sufficiently showing a wide difference between them.

Ischium.—Plate XXX., Fig. 5, reduced to one half.

The narrow extremity of the bone given in this figure, we presume to have been the acetabular, but destroyed; the opposite end, which is of considerable width, joined its fellow ischium on the median line; it is in this part spread out very much, being 5 in. $\frac{7}{10}$ths across where widest, whilst at the opposite end it is only 1 in. $\frac{3}{10}$ths. The wide end is deeply concave in the middle, the lateral edges turning down; this inversion of the edges, although existing in the Crocodile, is much less in that animal than in our bone.

In the Monitor (Ouaran, *Lacerta Nilotica*) in our possession there is not so great a difference in the two ends of the Ischium, neither is the wide one so much hollowed; our fossil bone is likewise

much wider than in any of the family of the Lizards, and it approaches more nearly to the monitors and crocodiles than to any other recent genus.

Tibia.—Plate XXX., fig. 6, reduced to one half.

This bone we conceive to be a tibia, but its outlines and extremities are so much dilapidated, that we are not able to make out a further determination.

Fibula.—Plate XXX., fig. 7, 7 a. natural size.

This figure represents a left fibula detached from the matrix; the superior half only remains, but it is in a perfect state.

7 a. Is a section of the superior edge.

The bone more nearly resembles the fibula of a Crocodile than any other.

Metacarpal or Metatarsal Bones and Uncial Phalanges.—Plate XXX., fig. 8 to 13, natural size.

These bones belong to the extremities, but whether to anterior or posterior we do not attempt to decide. It is probable, from the elongated character of fig. 9, that it is a metatarsal or metacarpal bone. Fig. 8 is evidently one of the phalanges, probably a penultimate; its great difference in transverse diameter shows that it could not have belonged to the same member as fig. 9.

Figs. 10 to 13 are evidently uncial phalanges, and present all the characters of those of a Saurian. Fig. 10 measures 2 in. $\frac{4}{10}$ths along its convex edge, its articular extremity is hollow, and has a process projecting considerably backwards, on its upper and lower edges. This form of its articular cavity would evidently prevent extension as well as flexion to any great extent.

Conclusion.—The considerations which arise from the study of these remains are various and important; and we have a further proof of the truth of the opinion, that the more ancient the strata, the more the animal remains differ from existing types.

In the specimen of the lower jaw, we have an animal with teeth contained in alveoli, a character separating these remains from all recent Lizards, and, connecting them with those Saurians having alveoli, as the Crocodiles, another of the many instances of extinct types intermediate to the existing ones, the antiquity of these remains being greater than that of any other vertebrated animals excepting Fishes; the sutures connecting the annular portion of

the vertebra bring them nearer the Crocodiles of the recent genera and the Enaliosaurians of the extinct.

The double concave system and the biconical form of the bodies or annular portions are worthy of notice as characteristic of all the older Saurians yet discovered, as well as an approach to that of Fishes found in strata of a still earlier date. In the chain-like shape of the spinal canal, or, in other words, the difference in vertical diameter of the canal corresponding to the middle of each vertebra, we have a character entirely new to us; we shall avail ourselves of further opportunities to observe it.

XXVIII.—*Extracts from a Memoir on the Geological Structure and Phænomena of the County of Suffolk, and its Physical Relations with Norfolk and Essex.*

By the Rev. WILLIAM BRANWHITE CLARKE, M.A., F.G.S.

[Read January 4th and March 8th, 1837.]

THE observations detailed in this memoir were made during 1827, 1828, and 1829, and are arranged under the heads of the physical features of the county, the geological structure, and the effects produced by the causes now in action.

1. Physical Features.

The general form of Suffolk is an oblong, of about 47 miles by 27, bounded on the east by the German Ocean, on the south by the river Stour, on the west by the Ouse and Lark, and on the north by the Little Ouse and Waveney. It is impossible not to be struck with the fact, that whilst some of these rivers have a direction from east to west, others flow from N. N. W. to S. S. E., and that the coast section from Harwich to Orford is nearly parallel with the direction of the Waveney; and if these observations be extended to the adjoining counties of Norfolk and Essex, which are similar in geological structure, an accordance will be found in the direction of the rivers Chelmer, Colne and Blackwater, and in the estuaries of the Thames and the Crouch.

How far these river-channels may be due to dynamical action, it is difficult to determine; but I am of opinion, that when they are studied with reference to the proofs of violent derangement in the north, east and west corners of Norfolk, and the almost unequivocal testimonies of disturbance on the coast of Suffolk, there is sufficient reason to assume that the drainage of Norfolk, Suffolk and Essex, has been induced by a violent strain acting from below, and throwing the whole mass of the country into a position, by which 1200 square miles of Norfolk, and 220 of Suffolk, are drained by Yarmouth Haven, and about 2000 square miles of the latter county, at the S.E. corner.

Mr. Woodward, in his "Outline of the Geology of Norfolk" (pp. 1, 2), observes, that from the high ground between Lopham Ford and Brancaster, where the Waveney and Ouse rise within a few feet of each other, and diverge, the rivers of Norfolk flow eastwards and westwards, according to the

inclinations of the chalk; and that the valleys of Norfolk are valleys of elevation due to the elevation and fracture of the chalk; and in these statements I fully concur.

In addition to the preceding facts it may be added, that the estuaries of the Alde, the Deben, the Orwell, and the Stour, meet the fresh water at nearly the same distance, 11 or 12 miles, from the sea, and at the boundary line of the great continuous bed of diluvium, which covers so extensive an area in that part of England, patches only, of greater or less extent, being found to the east of the line.

2. The Geological Structure.

The formations of which Suffolk consists are, 1, chalk; 2 and 3, the plastic and London clays; 4, crag; 5, diluvium, or ancient superficial detritus; and 6, recent lacustrine deposits; the first occupying the N.W. portion of the county; the second, third and fourth, the S.E.; and the fifth, or diluvium, the intermediate part, resting on all the preceding deposits; while the sixth, or lacustrine accumulations, are of very local occurrence.

1. *Chalk.*—In the S.E. of Suffolk this formation contains the usual plates and nodules of flints, and the fossils characteristic of the upper chalk. In making a well at Harwich, the workmen penetrated, at the depth of 94 feet, and between the white and grey chalk, a stratum, 10 feet thick, of sandy, gritty chalk. The beds are in general nearly horizontal; but they are sometimes inclined at considerable angles, and the surface appears to have been violently dislocated, and worn into deep gullies, called, locally, sand-galls. At Harwich, in making two wells, only 70 yards apart, the chalk was reached in the northern at the depth of 88 feet, but in the southern at 64 feet. The variation in the dip of the beds is considerable. At Shelley and Creeting they rise to the N.E.; at Monk's Eleigh, scarcely 9 miles distant, to the S.W., at an angle of 15°; at Offton the rise is also to the S.W.; but at Hartest to the N., and at Blakenham to the S.*

The general slope of the chalk is from N.W. to the sea. At Sudbury, where it cuts the Stour level, it is about 70 feet above the sea; and at East Bergholt about 16 feet; but at Harwich, from 64 to 88 feet below the sea-level. Again, at Wickham Market the chalk was reached at the depth of 160 feet; and at Woodbridge, six miles distant, at 250 feet from the surface.

Where the formation has been denuded by the rivers, the tertiary beds frequently rest upon it; but where it rises into an elevation above the river-levels, it is covered altogether by diluvium.

* For references to detailed sections of the chalk, see numerical index, p. 369.

The formation is principally exposed in the banks of the estuaries and rivers. Thus, along the course of the Lark and Ouse, it is visible at Bury, Horningsheath, Westley, Great Saxham, Little Saxham, Barrow, Welnetham, Fornham All Saints, Fornham St. Geneviève, Fornham St. Martin, Livermere, Ixworth, and thence by Watesfield to near Botesdale. In the valley of the Gipping chalk is exposed, though not continuously, from Stowmarket to Whitton; coming to the surface at Whitton, Creeting, Blakenham Magna, Blakenham Parva, Claydon, Somersham, Coddenham; and in the adjoining parishes at Crowfield, to the east of the Gipping, and at Witnesham, where it forms a considerable hill. At Crowfield and Coddenham the chalk is without flints. In the valley of the Stour it appears at Sudbury, Great and Little Cornard, and Chilton, extending nearly to Long Melford. At Ballingdon Hill, opposite Sudbury, chalk has been excavated to the depth of 40 feet, under 123 feet of diluvium; and at Hartest, about eight miles to the north of Sudbury, it occurs, dipping rapidly to the south. At Shelley, near Higham, where the Bret joins the Stour, chalk occurs, close to the church, and in the river bed; it is also visible between Lavenham and Shelley; and it has been quarried under the clay at Well's Hall, in Brent-Eleigh (Bundilly), Baker's Farm, and Chellesworth. At Monk's Eleigh, (Monk Silly) between Chellesworth and Sudbury, the chalk strata dip rapidly to S.W.; at Semer it crops out close to the river, and is covered by 50 feet of clay and gravel. Chalk is also dug at Cockfield and Bradfield, between Lavenham and Bury. At Hadleigh, between Shelley and Lavenham, the chalk is 102 feet below the surface. It occurs also at Aldham, Needham (18 feet from the surface), Nedging, at a great depth, Whatfield (40 feet), Wattisham Offton, Willisham (146 feet), Barking (94 feet), Flowton (90 feet), Bramford Hall (90 feet), Willisham Hall (200 feet), Creeting (23 feet); above the valley of the Stour it has been found at East Bergholt (126 feet); at Helmingham Hall, to the east of Coddenham (57 feet); Wickham Market (160 feet); Woodbridge (250 feet), 150 feet also of chalk, with flints, having been cut through; Woolpit (40 feet); and at Harwich, as already stated, it was found, at the depth of 64 feet, in West Street; and 70 yards to the north, at 88 feet from the surface.

2. *Plastic Clay.*—There is some difficulty in separating this deposit from the diluvium of Suffolk. At certain points, however, as at the chalk-pit near Shelley Church (see section 16, p. 373), the brick-pits at Higham Bridge (see p. 372), the St. Helen's brick-pits at Ipswich (see p. 382), at Bramford (p. 380), Whitton (p. 379), Great Cornard, near Sudbury, Harwich (p. 370), East Bergholt, Brent Eleigh, Copdock, the descent from Flowton to Offton, between Offton and Bramford, and at other places, it presents beds of mottled clay, sand, or pebbles, agreeing in character with the strata of plastic clay in other parts of the kingdom*. From its occurring only at detached points, I am of opinion that it has been exposed to great denudations; and from its position at particular localities, that it has partaken, in part at least, of the dislocations which have affected the chalk.

3. *London Clay.*—This formation presents, in Suffolk, the usual characters, and contains layers of cement stones. At Walton-in-the-Naze, and Bawdsey (Plate XXXI., fig. 2.), considerable quantities of pyritous vegetable remains are washed up from a bed below the level of the sea; and they rival in variety and abundance the Sheppey fossils.

* For references to detailed sections, see numerical index, p. 369.

The furthest western or inland point at which the formation is visible, is at Layham, near Hadleigh*; the country beyond being covered by diluvial clay. It constitutes, however, the substratum of all the districts intersected by the estuaries of the S.E. of Suffolk†, and the coast section from Orford Ness to Walton Naze (Plate XXXI., fig. 1 to 5 and 7), being everywhere capped by crag, except at Havergate Island, in the Ore. This section is constantly varying in its features, but presented, when I examined it in 1827, the appearance of beds once horizontal, having been upheaved in some places, and depressed in others; but to what extent these disturbances may have been produced by elevatory movements, the action of the sea, or the undermining of land-springs, I could not satisfactorily determine. The supply of water obtained from the formation appears to be governed by local phænomena. At East Bergholt a well was dug, to the depth of 40 feet, in London clay, without success; but in excavating a cellar at the distance of a few feet, a copious spring was tapped, and conveyed into the well by a channel. In the river Ore is an island of London clay, in which two wells were sunk through 80 feet of clay, 3 inches of rock, and 20 feet of sand. The water rose to the surface, had a strong smell of sulphur, but no saline taste, though it overflowed only during high tide in the river.

The fossils are confined to fishes' teeth, and the occasional occurrence of shells; but in the clay of the West Rocks, off Harwich, fossil turtles have been found.

4. *Crag*.—The term crag is applied in Suffolk only to the shelly beds, and the word gravel to the associated beds of pebbles, as well as to the accumulations of superficial drift stones. The portion of the country occupied by the deposit, is bounded on the west by a line, connecting the water-head of the estuaries; and the most southern part at which it is now visible are Blackbrook Hill, near Dedham, and Langham. The patch at Walton Naze has been considerably reduced by the partial destruction of the cliffs (Plate XXXI., fig. 4, 5, and 7.). The sand, however, in which the shells occur at Blackbrook, I have traced to Ardleigh Wood near Colchester, and it is said that Danbury Hill, near Chelmsford, is capped by crag, but I doubt the accuracy of this observation. The general area of the surface occupied by the formation within the county of Suffolk‡, is a platform of nearly uniform elevation, but it has been worn into ridges and valleys, apparently by currents acting in parallel lines from N.E. to S.W., and the cliffs both in the interior and on the coast are sections of these ridges. The

* See postscript at end of sections, p. 383.

† For references to detailed sections, see numerical index, p. 368.

‡ For references to detailed sections, see p. 368.

dip and inclination of the crag agree with those of the London clay, and therefore I infer, that both were denuded by the same currents, and while they were beneath the level of the sea, and that they were equally acted upon by the same elevating movements. According to my observation, the deposit nowhere extends beyond twelve or thirteen miles from the coast, and at Pakefield, where the diluvial clay comes to the very edge of the sea, it disappears as a surface deposit, but re-appears at intervals further north between that point and Cromer. Though crag is undoubtedly discoverable here and there, *in situ*, as a regular formation north of the Waveney, yet I by no means allow that it is regularly stratified as an undisturbed deposit between Leiston and Pakefield. I am fully convinced, from observation, that the diluvial clay and crag are distinct deposits; and I am almost equally convinced that, if the crag has any share in the formation of the cliffs between the Blithe and Lake Lothing, it has been affected by disturbances of a similar nature to those which are presented in the cliffs of East Norfolk. That the crag may have occupied the localities, there is no reason to deny; but they now present no traces of an undisturbed deposit.

To the previous descriptions of the structure of the crag, I have nothing to add, except that where the shells are not visible, the sands contain a slight mixture of calcareous matter. I object to the separation of the beds with shells from those without; as the shifting of a sand bank would correctly account for the occasional occurrence of beds thirty feet thick resting upon strata inclosing testacea.

Believing that the true rationale of the crag is to be found in the hypothesis of sand banks inhabited by testacea, and situated in a tidal way exposed to violent fluctuations of the sea, as well as subject to drifts of extraneous matter from land waters, I see nothing extraordinary in the idea that accumulations of sand and shingle may have formed a part of that deposit in which the crag is regularly stratified; but I cannot consent to such accumulations, though contemporaneous with the crag, being classed with it under that name; much less can I consent to diluvial clay being also included in it.

If, then, we assume that in the tertiary sea sand banks were formed, around the shelves and under the lee of which testacea collected, lived and died, as at present, many of the phænomena of the crag may be readily solved; and we shall not need to wonder why the bivalve shells are found lying with the flat sides to the strata of sand, why the young are congregated in one group and the old in another, why flints and pebbles are found covered with balani, or why the remains of terrestrial mammalia are associated with those of whales and fishes.

With respect to Mr. Charlesworth's subdivision of the crag into two ages, I fully agree, with a qualification of the word age. If that gentleman had said different periods of the same era, I could find no difficulty in admitting the justness of the classification, as not only the species but genera of shells are differently grouped according to localities. The Norwich crag, I also admit, differs from the Suffolk; and, on the authority of Mr. Woodward, I may state, that bowldered Suffolk shells occur in the beds at Thorpe. The corals of the lower bed, I am of opinion, betoken a warmer climate; and if during the crag era the earth gradually cooled, the change from a coralline deposit to one more nearly related to the inhabitants of the present era, would be the natural and inevitable result.

I fully assent, also, to the observations brought forward by Mr. Charlesworth in a paper read before the British Association at Bristol, on the mixed nature of the deposits now forming on the coast of East Anglia, in which the fossil remains of the adjacent cliffs are intermingled with the shells of existing species; and I was acquainted with examples long before the reading of that paper.

As to the necessity of separating the diluvium from the crag, there can be no question. The gravel found in the latter, if carefully examined, will be acknowledged to differ from regular diluvial gravel: its occurrence only betokens diluvial action during the period of the crag. That such actions have been often repeated there can be no doubt, for the beds of superficial gravel of Suffolk and Dorsetshire are evidently not of one period; and no one who has studied gravel deposits accurately, can refuse to admit, that there have been more than one occurrence of diluvial action, after the deposition of the tertiary formations. In Norfolk, it is true, that crag is involved in the clay; but if this clay, which in that county is 400 and in Suffolk 300 feet thick, be one with the crag, it is most curious that a line of demarcation should actually exist between the districts in Suffolk, occupied by these deposits, and that the clay is never found below or intermixed with the crag. Moreover, this diluvial clay has been traced not only into Norfolk, but into Cambridgeshire and Essex, close up to the metropolis. In Suffolk the same line which bounds the London clay bounds the diluvial. The only rational conclusion is, that during the crag era, an extraordinary convulsion took place, which shook the whole country. Diluvial clay and gravel occur in cavities in the crag on Alderton Common, and near Stratford St. Mary's, at the sixtieth mile-stone from London. (Plate XXXI., fig. 6.)

Respecting the conchological history of the crag I offer no remarks; partly because it does not fall within my object in writing this paper, and partly because the notes, which I formerly made, have been lost.

*Diluvium**.—The diluvium of Suffolk may be divided into three classes: 1. clay; 2. gravel; 3. erratic blocks.

1. *Diluvial clay.*—This deposition covers a great portion of the county, and extends into Norfolk, Cambridgeshire and Essex, rising to a considerable elevation in High Suffolk, and having, near Cromer, a thickness of 400 feet. A large portion of the clay is of a yellowish hue, but the greater part is blue; and both varieties contain chalk pebbles, sometimes disposed in layers, but more commonly dispersed, a character by which the diluvial clay may be distinguished from the London or plastic clays. It is difficult to determine the origin of this argillaceous deposit; but I am inclined to think that the yellowish portion may have been derived from the plastic clay, and the blue, in consequence of its peculiar fossils, from the clays below the chalk. Fragments of coal have been found in the diluvium at Lavenham, also fragments of mica slate containing garnets and tourmaline. Specimens of a similar rock were found by Mr. R. C. Taylor at Cromer, with masses of granite, porphyry, trap, oolites, and every other rock above the coal-measures. At Ballingdon Hill, near Sudbury, Mr. Brown has procured thirty varieties of primary, secondary and tertiary rocks. Comparatively few flints occur in the clay. At Ickworth, a beautiful specimen of the Dudley trilobite was obtained in making a drain, and at various other localities, numerous tertiary and secondary fossils abound. It is inferred that the clay contains cavities, as streams of foul air occasionally issue from fissures.

It is difficult to define accurately the boundary of the clay. Smith's map is correct in the general outline. The eastern limits range from Wangford near Southwold, with occasionally slight interruptions, to Parham, Otley, and Henley. Passing the Gipping, it extends to Shelley, and thence to Clare, Haverhill, and Newmarket. From the last locality it may be defined by a line passing from the edge of the chalk to the N.W. into Norfolk.

2. *Gravel.*—The gravel is less generally diffused than the clay, and though there are instances in which it underlies the clay, and others in which the two are mixed up, yet I consider the gravel to have been partly deposited at a distinct period. In some places, as near Sudbury, it consists merely of unrolled flints; in others, large masses of flint, slightly mixed with chalk pebbles, are imbedded in sand; and occasionally, flints are intermingled with bowlders, of various dimensions and sometimes unknown origin. Many of the extraneous fragments found in the gravel, I think may have been washed out of the clay; and I am of opinion that the river valleys have been excavated both through the clay and the gravel. With regard to the relative propor-

* For references to detailed sections see the numerical index, p. 368.

tional quantity of each ingredient, the chalk flints are the most numerous, primary and transition rocks the next in abundance, and secondary and tertiary the fewest in number; the absence of the latter being easily explained by their inferior hardness. At Stratford St. Mary, and East Bergholt, I have collected specimens of nearly every rock in England to the N.W. of Suffolk.

3. *Erratic Blocks.*—These bowlders consist of granite, porphyry, basalt, limestone, and the sandstones of the various formations, and occur in great abundance, and occasionally of vast size. They are sometimes found in the river valleys, and sometimes on the level platforms and hills. They agree in lithological characters with the smaller fragments of the gravel, and are considered to be of the same diluvial origin, but are so conspicuous as to deserve a distinct notice. Among numerous other localities I may mention Copdock, East Bergholt, the valley between Thorington Street and Scotland Street, near Stoke; and at Flatford Mill in East Bergholt parish.

Lacustrine Deposits.—Under this head I must notice the bed containing freshwater shells, discovered by Mr. Charlesworth and Mr. Searles Wood * on the banks of the Stour at Stutton, and that described by Mr. Brown, at Copford near Colchester†, which contains similar shells, also bones of the Ox and Deer: accumulations at Grays near Purfleet and at Southend in Essex, inclosing the same testacea, but associated with the remains of the elephant, rhinoceros, deer, ox, bear, &c. have been described by Mr. Morris‡.

Causes in action.—Under this head I shall confine my observations to the action of the sea on the coast, the changes produced by fluviatile accumulations being of little importance. My first acquaintance with the coast about Bawdsey was in 1814, between which period and 1829 a battery which stood 100 yards beyond the present low-water mark has been dismantled, and the life-boat house has been three times removed to a distance of a quarter of a mile at least in rear of its original position. The destruction between the Alde and Bawdsey Cliff during the last twenty years is calculated to have been upwards of 100 acres, and the coast between that cliff and Bawdsey Haven is said to have diminished about two yards annually. Similar remarks apply to the cliff between the Deben and Harwich Harbour, batteries and martello towers having been successively undermined. During the time of the Romans there was a castle in the cliffs at Felixstow, built by Constantine to guard the entrance of Orwell Haven. Holingshed says the earl of Leicester landed there in 1173; but in 1176, Henry II. overthrew the castle. In 1722 the ruins extended 100 feet in length, were 5 feet high and 12 feet broad; pebbles

* Mag. Nat. Hist. vol. vii. p. 274. † *Ibid.* vol. vii. p. 436.

‡ *Ibid.* vol. ix. p. 261. See also his paper on the deposits in the valley of the Thames, M.N.H. vol. ii. N.S. p. 539.

and Roman brick being the principal materials. Lumps of the walls were then visible upon the shore, and at low water in the sea. The cliffs were at that time about 100 feet high. In 1740 some of the ruins still existed; but in 1766, Grose says the remains of the castle were visible at low water, the cliff being gone, and he adds, that a person, then living, remembered the ruins 50 yards within the cliff top. In 1829, when I had the cliffs measured, they varied from 20 to 80 feet in height. According to the above statement, at least 200 yards have been destroyed within the last century.

In 941 the church at Walton Naze stood a considerable distance inland; about 50 years since the church and burial ground remained, but now not a fragment of either is left. In 885 a battle was fought between Alfred and the Danes at the mouth of the Stour, where the shingle bank now is.

Harwich also is said to have arisen, in consequence of the destruction of Orwell, which stood on the spot now termed the west rocks, and was swallowed up by an inroad of the sea since the conquest. While this destruction is proceeding on one part of the coast, new sand banks are accumulating at others, by which the ancient entrance in the estuary of the Stour and the Orwell has been filled up, and those rivers compelled to make a new line of communication with the sea.

The following conclusions I conceive may be deduced from the statements given in the body of the memoir from which the above extracts are taken.

1. The substratum of the whole of Suffolk, Norfolk, and Essex is chalk, which appears to have been dislocated and worn into deep hollows by the action of water, previously to the commencement of the tertiary era.

2. On this abraded surface the plastic clays and sands were formed, but not over the whole area.

3. Partly on these beds and partly on the chalk the London clay was then deposited, but to no very great thickness in Suffolk.

4. Upon the London clay as well as the chalk the crag was next accumulated upon sand banks produced by the tidal waters and currents, and around projecting masses of chalk.

5. While the crag still lay beneath the sea, a violent catastrophe broke up many of the secondary strata, from the chalk to the lias inclusive, and the debris thus caused, together with numerous masses of ancient rocks, was spread by a rush of water over the surface of the tertiary formations and the chalk, in some places to a depth of 400 feet, constituting the beds of drift clay, &c., which occupy so great an area in Suffolk; and it was extended to the edge of the then existing sea coast, which appears to be defined by the western limit of the crag.

6. Previously to this diluvial action, and after it, the inland waters of the then dry land bore to the sea, animal and vegetable remains, vestiges of which occur on the Norfolk coast and elsewhere.

7. The climate of this part of the globe was then different from the present.

8. After this period, and probably in prolongation of the first great catastrophe, a series of shocks acting from below shattered the surface, and gradually elevated the whole district, including the chalk, till the crag obtained the height of nearly 100 feet above the level of the sea; and by this movement were produced the valleys or lines of fissures through which the drainage of the county is effected; and during this operation the beds of gravel were partly accumulated.

9. No great convulsions have since taken place.

10. By the action of springs and the constant battering of the sea, the superficial contents of the London clay and crag have been reduced several miles, vestiges of their former extent being traceable in rocks and sands nearly always submerged.

11. By the set of the tides, vast accumulations of shingle and sand have been formed at projecting points, protecting, in some places, the cliffs from further destruction; but at Harwich Bay they have blocked up the ancient estuary, and compelled the Stour and the Orwell to form a new outlet.

12. The average amount of annual degradation of the coast is about two yards in breadth; and, in consequence of the conformation of the ridges of crag and London clay, the cliffs will gradually diminish into a low, sandy shore. The period estimated for effecting this destruction is calculated to be another century.

The following account of wells and sections was obtained by personal observations or from authentic information, and it is given to assist in illustrating the preceding remarks. The localities are disposed geographically for the sake of comparing the sections nearest each other; but to enable the reader who may wish to study the structure of the different deposits at all the points mentioned, the accompanying numerical lists, arranged under each formation, are added.

Diluvium, Nos. 2, 3, 6, 8 to 12, 14, 15, 18 to 37, 39 to 50, 52 to 54, 58, 60 to 64, 66? 67 to 71, 73, 74, 76 to 82, 87, 88, 93 to 96.

Crag, Nos. 5, 10, 13, 50? 81 to 87, 90 to 95.

London Clay, Nos. 1 to 7, 9 to 14, 17, 50? 51? 55, 56, 57, 65, 72, 80, 86, 89, 90, 92, 95, 97.

Plastic Clay, Nos. 1, 6, 7, 9, 13, 16, 17, 18? 29, 37? 38, 40, 42 to 46, 48, 49, 50? 55, 59, 60, 65, 67? 72, 75, 89, 95, 97.
Chalk, Nos. 6, 7, 9, 18, 20, 21 to 23, 25, 51, 59 to 65, 68 to 71, 74, 76, 95.
Green Sand, Nos. 9, 51.

No. 1. Well at Halstead, Essex.

	Feet.
1. London clay—loam	20
2. Plastic clay—gravel	6
3. sand	5
4. silt or sand	3
Total	34

Water instantly rose.

No. 2. Well at Weeley barracks, Essex.

	Feet.
1. Diluvial gravel	20
2. London clay, with septaria	126
Sand	
Total	146

Water rose instantly, and stands 50 feet deep.

No. 3. Wells about half way down East Hill, Colchester.

	Feet.
1. Diluvial gravel and earth	16
2. London clay	66
Sand	
Total	82

Water instantly rushed up and stands 15 feet deep, increased to 25 by land springs in wet seasons. This agrees with the well at the Barrack ground, which is 108 feet deep (Conybeare and Phillips's Outlines, p. 33.), the levels of the surface according.

No. 4. Well about $1\frac{1}{2}$ miles from Ardleigh towards Colchester, and nearly level with the kiln yard.

	Feet.
1. London clay, red	20
2. do. blue, containing oysters at the depth of 103 feet	90
Sand	
Total	110

The water stands 20 feet deep.

No. 5. Section of the escarpment of the Barrack Cliff, Harwich, 1829.

	Feet.
1. Crag—red gravel and sand	20
2. crag shells in fragments	
3. Upper London clay—mottled clay, white reddish and grey clays; bluish-grey and blue clay	
Carried forward	20

		Feet.
	Brought forward..	20
4.	Lower London clay—ten layers of green pyritous clay each 1½ inch thick in blue clay	
5.	blue clay, thin seam	
6.	two layers of green pyritous clay.....	20
7.	blue clay with limestone	
8.	do. with two layers of pyritous green clay .	
9.	blue clay	
	Total ..	40

In 1834 Dr. Mitchell found the height diminished five feet, and no traces of crag. The slope of the cliff to Harwich shows that it was once much higher; if continued to the "west rocks", the height would perhaps be about 100 feet,—the probable greatest height attained formerly by the coast from Hollesley Bay to Walton Gap.

No. 6. Harwich, well made in West Street, and discontinued.

		Ft.	In.	Ft.
1.	Diluvium—earth.....	3	0	
2.	sand (salt spring)	12	0	
				15
3.	London clay—"platamore".....			9
4.	Plastic clay—shingle and gravel	12	0	
5.	red sand	9	0	
6.	coarse gravel	6	0	
7.	coarse dark sand	9	0	
8.	green and red clay interspersed	1	6	
9.	green clay	2	6	
				40
10.	Chalk—containing pyrites and echini	30	0	
11.	do. and a peculiar white sand	10	0	
				40
12.	Chalk marl—grey chalk, with shells.....	72	0	
13.	chalk marl.....	60	0	
14.	Boring continued 121	0		
				253
	Total..			357

No. 7. New boring, Harwich, commenced 1826, discontinued 1827, 70 yards north of No. 6.

		Feet.
1.	London clay—greyish marly clay.....	70
2.	Plastic clay—compact clay, beautifully mottled red and lilac	10
3.	fine sand, with water containing 4 per cent. muriate of soda .	8
		18
4.	Chalk.....	192
	Total..	280

The surface of the chalk dips under West Street, 20 feet in 70 yards, or 1 in $10\frac{1}{2}$ feet to the north. In 70 yards also, the London clay deepens from 9 to 70 feet; and the plastic clay shallows from 40 feet to 18. The 8th bed of No. 6. appears to be the second of No. 7., and if so there are only 10 feet difference in level.

No. 8. Arnold's Well, East Bergholt.

		Ft.	In.
1.	Diluvium—gravel	3	0
2.	loam, gravel and sand	11	0
3.	clay	0	4
4.	sand (Spring)		
	Total..	14	4

This well gives an average of the surface soil in that parish; and the depth of 14 to 18 feet furnishes a nearly constant supply of water.

No. 9. Well at the Rectory, East Bergholt.

		Feet.	Feet.
1.	Diluvium—earth	2	
2.	red gravel	4	
		—	6
3.	London clay—yellow clay, growing darker	20	
4.	blue clay (with selenite)	97	
		—	117
5.	Plastic clay—black gravel		3
6.	Chalk		50
7.	Upper green sand—greenish sand and blackish earth		4
	Total..		180

N.B. The height of the surface is about 110 feet above the level of the salt-water bed at Cattawade*; the chalk consequently falls about 48 feet to Harwich, eastwardly. The plastic clay shallows also in that space from 18 to 3 feet; and the London clay deepens from 9 to 117 feet. It will be also seen that the general depth from the top of the cliff at Harwich to the chalk there, agrees within a few feet of the depth at Bergholt to the chalk, and within a quarter of a mile from the well No. 8., and within a few rods of No. 9. the crag appears in a very thin stratum.

* Catiwade? (*Cati vadum*) head of the Stour estuary at Brantham, near Bergholt. See Tacit. Annal. XIV. 32.

No. 10. Dedham Gun Hill, (ascending series) 2¼ miles from East Bergholt, to the S.W. (ascending order).

	Feet.
London clay—floor of Toll-gate house above river, about	20
Crag makes its appearance above the level of the floor of the Toll-house, on the side of the hill, about.....	30
Crag	20
Diluvium—gravel and sand, to top of field above the Gun inn	36
Total..	106

No. 11. Well at Mr. Downes' residence, near the Lamb inn, Dedham, about the level of No. 10. This is an approximation only by levelling, but it agrees with the general level of the London clay and crag, &c., on the Suffolk side of the Stour, as may be seen by comparing this section with the well, No. 8., and the level of the chalk, &c., at Shelley, No. 16.

The level of the river at the Toll-gate, is about 14 feet above the salt-water bed.

		Ft.	In.	Ft.	In.
1.	Diluvium—earth (provincially *Calerer*)	1	6		
2.	gravel.....	1	0		
3.	brown clay	5	0		
4.	gravel.....	1	0		
5.	red sand	1	3		
6.	dark grey sand (land spring) ..	0	3		
7.	gravel	0	3		
				10	3
8.	London blue clay (left off)			10	0
			Total..	20	3

No. 12. Wells at Pig Lane, Dedham.

1. Surface beds, from ..... 16 to 60 feet.
2. London clay ..... 28 to 37 feet.

No. 13. Brick-kiln pits, Higham Bridge, near the junction of the Bret and Stour rivers, 2 miles to the N.W. of Dedham.

1. Upper part of hill, gravel and sand, apparently belonging to the crag formation.. 10 feet.
2. London blue clay..... 70 to 100 feet.

Pit 2.

		Feet.
1.	Earth	4
2.	London clay—thick clay with limestone (effervescing)	7
3.	Plastic clay—brownish clay with clay nodules and vegetable impressions; it does not effervesce	29
4.	sand, white as silver, very fine, with argillaceous flakes	2 to 6
5.	black clay, like pitch	2
6.	sand	2 to 4—41
	Total..	52

Brown clay with ochreous concretions, depth unknown.

N.B. Strata horizontal; no fossils, and only a few rounded siliceous pebbles in lower beds.

No. 14. Mr. Harris's well, Higham Hill.

		Feet.	Feet.
1.	Gravel	10	
2.	Sand	20	
			30
3.	London clay	10	
	Total..		40

Sand. Water strongly impregnated with sulphur, and useless.

No. 15. Wells at Holton, $1\frac{3}{4}$ miles N.E. from Higham.

		Feet.
1.	Holton Hall Well, diluvial clay and chalk stones	40
2.	do. Rectory do., do.	42

No. 16. Chalk-pit near Shelley Church (west side of the ravine), about $2\frac{1}{2}$ miles south of Hadleigh.

		Ft.	In.	Ft.	In.
1.	Vegetable mould			5	0
2.	Plastic clay—chalky clay	1	0		
3.	white clay	1	8		
4.	ochreous yellow clay, containing large cetites	2	0		
5.	greenish clay, dotted with fuller's earth	4	0		
6.	reddish loam	2	0		
7.	hard bluish clay, with green particles, and siliceous pebbles	2	6—13	2	
8.	Chalk, very watery, containing large flints, to level of river			1	0
	Total ..			19	2

All the beds of plastic clay curved up to the north-west.

Assuming that the level of the Bret is about 23 feet above the salt-water at Cattawade, we find that the chalk slopes about 93 feet to Harwich, or rather

better than 6 feet per mile. A remarkably near agreement with this is afforded by the slope from Sudbury to Harwich, which makes the fall of the chalk about 6 feet per mile; at Sudbury the Stour is about 70 feet above the salt-water lowest level, and the cliff there is about 30 feet above the Stour; and consequently the difference of chalk level is about 150 feet in 25 miles.

No. 17.—Layham brick-kiln, 1 mile south of Hadleigh, 1½ mile north of No. 16, and about 30 feet above that level.

		Feet.
1.	Diluvial gravel	
2.	London clay, indigo blue, with pyritous nodules, black pyritous wood, yellow streaks of sulphur, containing septaria, shells (too crumbly to be ascertained), and sharks' teeth: the clay becomes brown	60
3.	Plastic clay—sand	3
4.	blue clay	4— 7
	sand (depth not known)	
	Total	67

In bed 2 there is a slip of at least 20 feet.

No. 18.—Wells at Hadleigh, sunk Nov. 1827.

		A. Feet.	B. Feet.
1.	Diluvial gravel	12	—
2.	Plastic clay—pure blue clay	90	70
3.	Chalk	28	30
	Total	130	100

The well A. is on a level with the river, and shows that the chalk at Hadleigh has been scooped into a hollow, since, at Shelley, it lies level with the river; and here, allowing 7 feet for the descent of the stream at the mill-lock, and 23 feet for the difference of height of the chalk in the river's bank at Semer and Shelley, it will make the slope of the chalk 4 feet per mile, and the hollow at Hadleigh 95 feet deep, the chord being 2½ miles.

For the wells between Hadleigh and Ipswich, see No. 78.

Nos. 19 to 23.—

	Wells at Kersey (19). 2 m. N.W. Hadleigh.	Whatfield (20). 2¼ m. N. Hadleigh.	Semer (21). 3 m. N.N.W. Hadleigh.	Monk's Eleigh (22). 4½ m. N.W. Hadleigh.	Bildestone (23). 4½ m. N.N.W. Hadleigh.
Diluvial clay	75[1]	40	—	62	60
Gravel	—	—	50	—	—
Chalk	—	66	22	—[2]	—
Total	75	106	72	62	60

[1] Sandy. [2] The chalk rises 7 feet above the river, about 3 feet below the level of this surface, only one mile distant.

No. 24.—Well at the Greyhound Inn, Lavenham, 7½ miles W.N.W. of Hadleigh. (Sept. 1827.)

		Feet.
1.	Diluvium—light-coloured yellow clay	14
2.	stiff blue clay, with many chalk stones	14
3.	dirty clay, and black sand-like garden mould	12
4.	clay, with chalk-stones and coal	30
5.	white and yellow sand, and gravel	6
	(Water instantly.) Total	76

At 50 feet mephitic air, which put out candles and killed chickens; and at 76 feet, such a noise for four days as alarmed the workmen: the water rose after it to 5 feet deep.

Well at the parsonage, 45 feet blue clay, containing a layer of chalk-stones; at the Cock inn, 45 feet clay; at the mill, 56 feet soil and clay.

No. 25.—Section at Balingdon, near Sudbury.

		Feet.
1.	Diluvial clay, with chalk-stones	126
2.	Chalk	37
	Total	163

No. 26.—Well at Clare, 6½ miles N.W. of Sudbury.

	Feet.
Diluvial clay	160

Water instantly rose to within 7 feet of the surface.

Nos. 27 to 30.—Wells at

	Hartest (27). 6 m. N.E. Clare.	Cockfield (28). 5½ m. E.N.E. Hartest.	Bradfield (29). 1½ m. N. by W. Cockfield.	Chedburgh (30). 6 m. S.W. by S. Bury.
	Feet.	Feet.	Feet.	Feet.
Diluvium—whitish clay	3	—	11	8
blue clay	300	126	100	28
Plastic clay—red sand[1]	—	—	34	—
Total	303	126[2]	145	36

[1] Not penetrated. [2] Water stands 30 feet deep; a second well at Cockfield gave 20 feet white clay, 10 feet blue clay, with iron pyrites, and shells which crumbled to pieces.

No. 31. Well at Chevington, 5 miles S.W. by W. from Bury.

		Feet.			Feet.
1.	Diluvial white clay	10	7.	Diluvial chalk	1
2.	blue clay	15	8.	blue clay	2
3.	blue gravel	1	9.	chalk	2
4.	blue clay	4	10.	blue clay	29
5.	chalk	1	11.	blue clay, with Belemnites, Gryphites, &c.	52
6.	blue clay	3		Total	120

No. 32.—Well at Ickworth House (Marq. Bristol), 3 miles S.W. from Bury.

		Feet.
1.	Diluvial white clay	12
2.	pipe-clay	4
3.	gravel	2
4.	blue clay	10
	Total	28

No. 33.—Wells at Bury.

A. To S.W. of Bury.

			Feet.
A.	1.	Diluvial gravel	2
	2.	clay	60
	3.	Chalk	120
		Total	182

B. 1. Plastic clay—yellow ochrey sand, cutting like leather, requires pinning..... 60
2. Chalk.

No. 34.—Well at Barrow, 6 miles west from Bury.

Diluvial clay .....(Water.)..... 130 feet.

N.B. Chalk hard by.

No. 35.—Well at Norton Hall, 7 miles E. by N. from Bury.

Blue clay—sand..... 75 feet.

No. 36.—Well at Tostock, 6 miles E. from Bury.

Gravel ..... 55 feet.

No. 37.—Wells at Elmswell, $1\frac{3}{4}$ mile E. of Tostock, or 5 miles N.W. of Stowmarket.

Diluvial clay..... 40 to 60 feet.
Plastic? sand ..... 20 to 33
Total..60 to 93

No. 38.

		Feet.
1.	Plastic clay—white clay	10
2.	gravel	10
3.	white clay	10
4.	blue clay (with iron-stone thick as a mill-stone)	20
5.	blue clay	43
	Total	93

Nos. 39 to 43.—Wells at

	Drinkstone (39). $5\frac{3}{4}$ m. W.N.W. Stowmarket.	Wetherden Hall (40). $3\frac{3}{4}$ m. N.W. Stowmarket.	Haughley Green (41). $3\frac{3}{4}$ m. N.N.W. Stowmarket.	Mendlesham (42). $5\frac{1}{2}$ m. N.E. Stowmarket.	Gislingham (43). $4\frac{3}{4}$ m. W.S.W. Eye.
	Feet.	Feet.	Feet.	Feet.	Feet.
Diluvial clay..	70	40	60	40	60
Plastic sand..	—	20	—	20	15
Total..	70	60	60	60	75

No. 44.—Well at Gislingham Parsonage.

	Feet.		Feet.
1. Diluvial white clay	10	5. Plastic blue clay	20
2. gravel	4	6. white sand	16
3. blue clay	10	7. gravel	40
4. Plastic clay—black sand	5		
		Total	105 (water.)

Nos. 45 to 49.—Wells at

	Aspal (45). 5½ m. S. by E. Eye.	Framlingham (46). 9½ m. S.E. Eye.	Baddingham (47). 3½ m. N.N.E. Framlingham.	Great Glemham (48). 3½ m. S.E. Framlingham.	Parham (49). 2½ m. S.S.E. Framlingham.
	Feet.	Feet.	Feet.	Feet.	Feet.
Diluvial clay	70	15[2]	80	20	25
Plastic sand	10[1]	25	—	20	30
Total	80	40	80	40	55

[1] Water instantly rose, and stands within 40 feet of the surface. [2] This clay was full of septaria and the usual fossils.

No. 50.—Well at Wickham Market, 5 miles S. from Framlingham.

	Feet.	
1. Blue clay	50	
2. Sand 3. Clay 4. Sands and gravel 5. Chalk	110	Particulars unknown, but probably crag, London clay, and plastic clay.
Total	160	(water).

No. 51.—Well at Helmingham Hall (Lady Dysart's), 7 miles W.N.W. from Wickham Market.

	Feet.
1. Mould	1
2. Clay, with shells	56
3. Chalk	30
4. Dark sand	5
Total	92

No. 52.—Wells in the Four Stonehams[1].

Diluvial clay..... 60 to 80 feet.

[1] In one well, at 64 feet, man killed, in 1829, by bad air. Lias fossils abundant.

No. 53.—Well at Old Newton, 2¼ miles N.N.E. Stowmarket.

	Feet.
Diluvial clay	50

No. 54.—Well at Stow Upland, near Stowmarket.

	Feet.
Diluvial clay	105
Sand	
Total	105 (water).

No. 55.—Well at Stowmarket.

	Feet.
London clay—dark, stiff clay	16
Plastic clay—sand	54
Total	70

No. 56.—Section at Stowmarket.

	Feet.
1. Soil	2
2. London clay—red clay	17

Bones of elephants found in the surface soil, and crumbling shells. Distance to the morass near the river, about 20 feet covered by diluvium.

No. 57.—Well at Great Finborough, 2¼ miles W.S.W. from Stowmarket.

	Feet.
1. Clay	90
2. Sand	30
Total	120 (water).

No. 58.—Well at Creeting All Saints, 1¼ mile N.N.E. from Needham.

	Feet.
Various soils	74
Diluvial gravel	10
Total	84

No. 59.—Well at Creeting St. Mary, 1 mile N.N.E. from Needham.

		Feet.	Feet.
1.	Mixed soil		7
2.	Plastic clay—gravel	4	
3.	blue clay	2	
4.	sand	10	
5.	rocky substance	2	
			18
6.	Chalk		175
	Total		200

No. 60.—Well at Creeting.

	Feet.
1. Diluvium—gravel	25
2. Plastic clay—siliceous pebbles in sand	5
3. Chalk	25
Total	55

No. 61.—Well at Needham Market, 1807.

	Feet.
1. Diluvium—gravel	10
2. dark blue clay, with chalk-stones	8
3. Chalk	
Total	18

No. 62.—Well at Needham Market.

	Feet.
1. Diluvial?—stiff loam	10
2. gravel	6—16
3. Chalk	24
Total	40

No. 63.—Well at Barking, 1½ miles S.W. from Needham.

	Feet.
1. Diluvial clay	94
2. Chalk	
Total	94

No. 64.—Average of wells at Coddenham, 3 miles E.S.E. from Needham.

	Ft.	Ft.
1. Diluvial sand, gravel, or clay, to chalk	5 to	20
2. Chalk (without flints) (water)	15 to	140

No. 65.—Well at Hemingstone, 3¾ miles E.S.E. from Needham.

	Feet.
1. London clay—loamy clay	10
2. Plastic clay, gravel, and sand	40
3. Chalk	45
Total	95

No. 66.—Well at Henley, 5 miles S.E. from Needham.

	Feet.
1. Clay	20
2. Gravel	40
Total	60

Nos. 67 to 71.—Wells at

	Witnesham (67). 6¼ m. S.E. Ipswich.	Blakenham Magna (68). 3¾ m. S.E. by S. Needham.	Blakenham Parva (69). 4 m. S. by E. Needham.	Willisham (70). 3 m. S.S.W. Needham.	Willisham Hall (71).
	Feet.	Feet.	Feet.	Feet.	Feet.
Diluvial gravel	—	10	—	—	—
clay	17	40	157	146	2
Plastic clay—gravel?	46	—	—	—	—
Chalk	—	92[1]	2[2]	3	190
Total	63	142	159	149	192

[1] No flints. [2] No flints; the water instantly rose to within 62 feet of the surface. Strata of chalk disturbed, inclined in opposite directions.

No. 72.—Section at Whitton brick-kiln, 2½ miles N.W. by N. Ipswich.

	Feet.
1. London clay—mottled clay	4
2. Plastic clay—sandy clay	1
3. clay, with siliceous pebbles	1
4. sand	20
Total	26

Nos. 73 and 74.— Wells at

	Barham and Claydon (73). 4½ m. N.N.W. Ipswich. Feet.	Bramford Hall (74). 3½ m. W.N.W. Ipswich. Feet.
Gravel	15 to 40	22
Chalk	———	108—130

Chalk-pit at Claydon, 150 feet deep.

No. 75.—Brick-kiln, Bramford, 3$\frac{1}{2}$ miles N.W. from Ipswich.

	Feet.
1. Clay	20
2. Sand and siliceous pebbles (Plastic clay)	20
Chalk at	40

No. 76.—Well at Flowton, 5¼ miles W.N.W. from Ipswich.

	Feet.
1. Diluvial clay	90
2. Chalk	4
Total	94

(At Flowton Hall, clay 94 feet.)

Nos. 77 to 79.—Wells at

	Elmsett (77). 6¾ m. W.N.W. Ipswich. Feet.	Hintlesham (78). 4½ m. W. Ipswich. Feet.	Copdock (79). 3 m. S.W. Ipswich. Feet.
Diluvial clay	10	15	15
Sand	46	21[1]	45
Total	56	36	60

[1] Gravel mixed with the sand.

No. 80.—Copdock brick-kiln (3 m. S.W. Ipswich,) and continuation through the parish. (Level under No. 79, at same distance.)

	Feet.
1. Diluvial red clay	3
2. Gravel	3
3. White sand	24
4. London clay	
Total	30

N.B. In the pit near by, diluvial gravel 40 feet thick.

No. 81.—Well at Belstead, 3 miles S.W. from Ipswich.

	Feet.
1. Diluvial stiff loam	15
2. Crag	35
Total	50

No. 82.—Well at Caple St. Mary, 5½ miles S.W. by W. from Ipswich.

	Feet.
1. Diluvial clay	45
2. Crag sand	40
Total	85

No. 83.—Well at Bentley Hall, 4¼ miles S.W. of Ipswich.

	Feet.
1. Sand	20
2. Crag	10
Total	30

Crag in Bentley lies on the surface also.

No. 84.—Hundred-house pit, Tattingstone, 4½ miles S.S.W. from Ipswich, 1828. Hill slopes to N.E.

1. Earth	2 inches
2. Sand and clay, agglutinated by iron, in layers as thick as a card	14 feet.
3. Large, very white, crag shells, here and there a flint or sandstone pebble crusted with *balani*	
4. Argillaceous shale, a line thick	
5. Very perfect white *young* crag shells, teeth and palates	

The strata lines converge to the west corner at an angle of 25° to 30°. The shells on the east side are large, on the west small.

No. 85.—Tattingstone-park pit, 4½ miles S.S.W. from Ipswich, 1828.

1. Earth	40 feet.
2. Sand, with iron lines	
3. Casts of shells as at Blackbrook	
4. White sand	
5. Red sand	
6. Crag	
7. Thin lines of micaceous sandstone	
8. Lines of red crag, with teeth	
9. White ditto	
10. Brown ditto	
11. *Unrolled* flint and *red sandstone* covered with balani	

The beds rise to N.E. At Bentley they rise to south

No. 86.—Well at Woolverstone, 3¾ miles S.S.E. from Ipswich.

	Feet.
1. Surface soil	1
2. Crag (with water)	30
3. London clay	
Total	31

Half mile from No. 86.

	Feet
Diluvial white clay	20
Crag sand	

No. 87.—Well at Wherstead, 2¼ miles S.S.W. from Ipswich.

	Feet.
1. Diluvial gravel	3
2. clay	6— 9
3. Crag	40
Total	49

No. 88.—Well at Ipswich, on high ground.

	Feet.
1. Loam	3
2. Gravel	49
Total	52

No. 89.—Brick-pits at St. Helen's, half way up to the Barrack Ground.

	Feet.
1. Earth	7
2. London clay—red loam	8
3. red clay, with streaks of sulphur	7
4. blue clay, with pyrites, sharks' teeth, and spots of yellow matter	20
5. reddish clay, with rock	7
6. Plastic clay—marl with white covering	2
7. sand, white with green particles	25
8. hard clay	
Total	76

Beds nearly horizontal or slightly inclined to S. by E.

No. 90.—Cliff at Bishop's Hill.

	Feet.
1. Crag	variable
2. London clay, brown growing blue, with layers of cement stone	70
Total	70

The beds dip from the chalk at Bramford to S.E. The Gipping at Bramford is 15 feet above the Orwell estuary.

No. 91.—Well at Rushmere, 2 miles E. by N. from Ipswich.

	Feet.
1. Loam (Diluvial)	14
2. Crag sand	52
Total	66

No. 92.—Pit on Rushmere Heath.

	Feet.
1. Crag sand	4
2. London clay	16
Total	20

No. 93.—Well in the Barrack Ground, Woodbridge.

	Feet.
Diluvium and crag—gravel and sand	77

(Water.)

No. 94.—Well at the entrance to the town.

	Feet.
1. Diluvial loamy soil	30
2. Crag sand	20
Total	50

No. 95.—Well at Post-office, Woodbridge, (particulars burnt in the fire at Rendlesham House).

	Feet.
1. Diluvium—(land spring)	
2. Crag and sand	40
3. London clay 4. Plastic clay	210
5. Chalk	150
Total	660

Water stands at 29 feet from the surface; it is very chalky and bad. There are 40 feet of copper pipe in the chalk.

No. 96.—Well at Hemley, 4¼ miles S. by E. from Woodbridge.

	Feet.
1. Loamy soil	6
2. Crag	44
Total	50

No. 97.—Well in Havergate Island, 8 miles S.E. from Woodbridge, (height of surface, 4 feet above low water mark of sea).

	Ft.	In.
1. London clay—blue clay, with usual rocky concretions	80	0
2. Rock	0	2
3. Plastic clay—sand	20	0
Total	100	2

N.B. The slope of the plastic clay, from Harwich to Havergate, gives about 5 feet in a mile; which agrees with the computed slopes of the chalk (see Nos. 16 and 18) the average of which is 5 feet; proving the original conformability of the beds. The distances and bearings are calculated from the Ordnance maps.

P.S. Since the above memoranda were committed to the press, I have been informed that cement stones have been found in great abundance at Assington, near Sudbury; but whether they belong to the beds of the London clay, or are drift septaria from the diluvial clay, I do not know. If the former, Layham (p. 362) is not the most westerly point of that formation. The statement requires authentication.

W. B. C.

Stanley Green, near Poole,
20th October, 1838.

XXIX.—*On the Geology of the Thracian Bosphorus.*

By HUGH EDWIN STRICKLAND, Esq., F.G.S.

[Read November 30, 1836.]

DURING a short residence at Constantinople, in March 1836, I made some researches into the geology of its vicinity. A very cursory examination sufficed to show, that the district was unexplored, and that the brief geological remarks, which exist in the works of other travellers, are very unsatisfactory. I therefore communicate my observations to the Society, in the hope that, though slight, they may serve as a guide to those geologists who may hereafter be induced to explore this interesting district*.

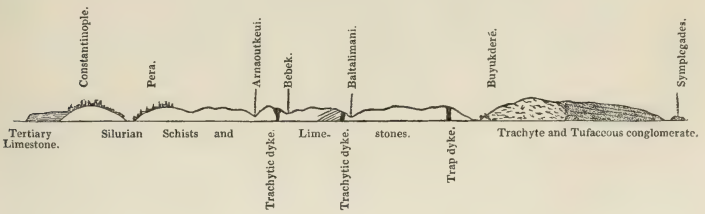
The formations in the neighbourhood of the Bosphorus may be classed as follows:—

1. Silurian schist and limestone.
2. Igneous rocks.
3. Tertiary limestone.
4. Ancient alluvium.

1. *Silurian Schist and Limestone.*

This formation occupies both sides of the Bosphorus for about three quarters of its length, and extends thence towards the W.N.W. and E.S.E., to an unascertained distance in Europe and Asia. It may probably form a great part of the Balcan range, of which the hills above the Bosphorus are a continuation.

Section west coast of the Bosphorus from the Sea of Marmora to the Euxine.



* These observations were made in company with Mr. Hamilton; but that gentleman being still on his travels, I have been deprived of his direct assistance in drawing up this paper.

The formation may be described as a mass of argillaceous schist, compact brown sandstone, and compact dark blue limestone, passing into each other by insensible gradations. The argillaceous schist predominates greatly over the other two rocks, and frequently exhibits an oblique or slaty cleavage. The whole formation bears a close analogy to the lower Silurian and upper Cambrian series, exhibited in Wales and Devonshire. From its resemblance to the type of northern Europe, Andreossy* and an American traveller† referred it to the transition series on mineralogical grounds alone; and this opinion is now confirmed by the discovery of organic remains, analogous to those of the Silurian rocks of Britain. This fact is interesting, from the extreme rarity of fossils in deposits of this early age in the southern parts of Europe.

The stratification of these rocks is in general much disturbed and contorted; and in other cases it is very obscure and difficult to detect. Hence it would require a closer examination than I was able to give, to establish the prevailing *strike* of the formation.

Organic remains appear to be extremely local, and were noticed in only two localities. The first of these is in the ravine above Arnaout-keui, a village about four miles from Pera, on the European side. The rock is an argillo-calcareous schist, splitting at an angle, oblique to the stratification. Impressions of various Brachiopoda and joints of Crinoideæ occur in it, lying in the planes of stratification. The substance of the shells has perished, leaving a brown dust; and the casts are in general much distorted by the compression and consolidation of the strata.

These remains were first noticed by M. Fontanier‡, who mistook the shells for Pectines, and thence inferred that this was a secondary formation. Had he examined them with more care, he would probably have agreed with M. Andreossy, who, without the assistance of organic remains, referred these rocks, as already stated, to the transition era.

The only other locality, where organic remains were seen, is on the hill called the Giant's Mountain, on the Asiatic side of the Bosphorus, about fifteen miles from Constantinople. It is singular that of three authors (Andreossy, Fontanier, and the author of "Sketches of Turkey"), who have noticed with more or less exactness the geology of this hill, not one has remarked the numerous and interesting fossils which occur there.

The lower part of the hill consists of compact limestone, thickly bedded, of

* Memoire sur le Bosphore. 8vo. Paris.

† Sketches of Turkey, by an American. New York. 8vo. 1833.

‡ Voyage en Asie Mineure. Paris. 8vo.

a dark grey colour, and slightly crystalline. It is exposed in extensive quarries, where it is traversed by some remarkable trap-dikes, to be mentioned hereafter. Organic remains are rare in the limestone; but I detected a few impressions of Terebratulæ and crinoidal stems, exhibiting the same crystalline fracture, which distinguishes them in the carboniferous and other limestones of England.

Above the limestone is an argillaceous schist, with an oblique cleavage, and it extends to the summit of the hill. Impressions of shells, similar to those of Arnaout-keui, occur in it in many places, and in tolerable abundance. I have found only one specimen, which can be referred to the family of Trilobites. It is a small fragment, but it so accurately exhibits the structure of the eye of an Asaphus, that I have no hesitation in referring it to that genus.

The following is a list of the fossils of this formation, as far as the imperfection of the specimens admits of identification. I am indebted to Mr. Murchison and Mr. James De Carl Sowerby for assistance in determining these fossils.

Brachiopoda.

1. *Spirifer.*—Allied to *Spirifer speciosus*, Bronn. Leth. Geog. II. 15.
2. *Spirifer.*—An undetermined species.
3. *Producta* (*Leptæna*) *sericea*?
4. *Producta* (*Leptæna*) *euglypha*? Dalm.
5. *Producta* (*Leptæna*).—New species.
6. *Terebratula affinis*, Min. Con.—In the Upper Silurian series of Great Britain.
7. *Terebratula unguis?*—In the Caradoc sandstone of Great Britain.
8. *Atrypa.*—An undetermined species.
9. *Orthis.*—New species.
10. *Orthis.*—New species.

Crustacea.

11. *Asaphus.*—Eye like that in Buckland's Bridgewater Treatise, pl. XLV. fig. 10′.

Crinoidea.

12. Detached joints of undetermined genera.

Polyparia.

13. *Cyathophyllum*, Goldf.
14. *Favosites*, Lam.—Similar to one in the Cambrian rocks.

Should any geologist ever devote that share of time and attention to this country, which it well deserves, he would probably find several other localities

for these Silurian fossils, and perhaps be rewarded by the discovery of many *Trilobites* and other organic remains, which I did not meet with.

The compact limestone of this formation is quarried in several places near the Bosphorus, especially at Baltalimani, where it dips to the westward. In the lower part the strata are thick, but they become thinner upwards, and, after assuming a concretionary structure, pass into argillaceous schist. The limestone exhibits some very obscure traces of organic remains.

The sandstones are best exhibited in the cliff between Scutari and Mondabornou. They are brown, commonly compact, sometimes schistose, and the stratification is distinct, being much broken and distorted.

The evidence of the organic remains justifies me in referring the formation to the Silurian system of Britain. The occurrence in this remote locality of rocks, which approach so closely to the type of north-western Europe, is somewhat remarkable; and the more so, as nothing of the kind occurs, as far as I know, in the more southern parts of Asia Minor, or in any portion of the Mediterranean basin. Many geologists are of opinion, that the transition and secondary rocks of northern Europe belong to a different type from those of the Mediterranean basin; and that the characters, both mineral and zoological, of these two parallel series present scarcely any common points of comparison. A line, nearly coinciding with the Pyrenees and Alps, appears to divide these two great basins, if we may so term them. Further investigations may perhaps show, that this line admits of being continued from the Alps through European Turkey to the range of the Mysian and Bithynian Olympus; and this may explain the appearance at Constantinople of rocks belonging to the type of northern Europe, which are wanting further south in Asia Minor.

The transition formations, which we have been considering, unite on the north to a mass of igneous rocks, and on the south-west to tertiary deposits. At present, I have no clue to the relative age of the two latter, but as the igneous rocks are in more immediate relation with the Silurian group, I will notice them next.

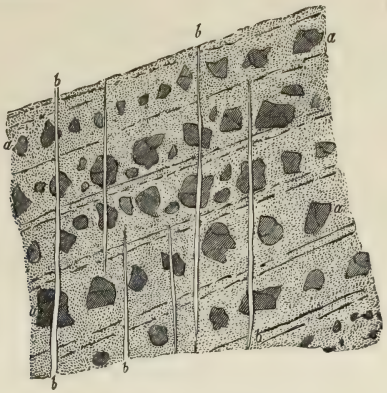
2. *Igneous Rocks.*

The igneous rocks of the Bosphorus may be described, in the aggregate, as consisting of trachyte and trachytic conglomerate. On the Asiatic side they commence, *en masse*, at Kavak under the old Genoese castle, and extend thence to Yoom-bornou on the Black Sea, or perhaps further. They consist chiefly of angular trachytic fragments, imbedded in a tufaceous paste. The conglomerates, viewed on the large scale, are distinctly stratified; and

from Kavak to Anadoli-fanar they have a regular inclination towards the north. They rest upon, or alternate with, trachytic rocks, more or less compact, and occasionally passing into phonolite and basalt. In some places, especially near Anadoli-fanar, dikes of the latter substance intersect the conglomerate beds. The basalt occasionally assumes a columnar form, which is seen in the greatest perfection at Yoom-bornou. The prevailing colour of these rocks is greenish, owing to the presence of copper, a circumstance which gave the name of Cyaneæ to the weather-beaten rocks of the Symplegades.

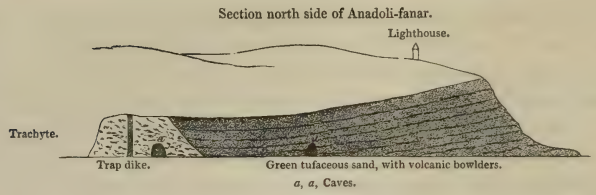
Near Filbornou the conglomerate contains bowlders of a brownish trachyte, softer than the greenish trachytic paste which envelopes them; hence they decompose with the weather, and give a honey-combed appearance to the rock. The contrary, however, is more often the case, when the imbedded fragments, being harder than their matrix, project above the general surface of the rocks.

These igneous formations contain many veins of red and white cornelian, and varieties of chalcedony. In one place near Filbornou the veins are perpendicular and straight, intersecting the conglomerate, and cutting indiscriminately through the tufaceous paste and the imbedded fragments.—See the accompanying wood-cut.



a, *a*, Angular trachytic fragments imbedded in a tufaceous paste.
b, *b*, Veins of chalcedony traversing both the fragments and the paste.

The deposition of these conglomerates appears to have been effected with the assistance, if not solely by, water. The fragments imbedded in them, though commonly angular, are sometimes rounded, and are contained in finely laminated strata of volcanic sand. An instance of this, on the north side of Anadoli-fanar, is represented in the following wood-cut.



On the European side of the Bosphorus, the igneous rocks commence on the north of Buyukderé. Here a species of trachyte of a yellow colour forms some considerable hills. It is much decomposed, and resembles loose sand, when viewed at a distance. Further north is a series of conglomerate beds, similar to those of the Asiatic side, and extending to the Black Sea.

These are the general features of the mass of igneous rocks, which abuts against the northern flank of the Silurian schists above described. The works of MM. Andreossy and Fontanier contain some information on their mineral contents.

A variety of trachytic and trap dikes occur in the Silurian schists, and are doubtless connected with the general mass of igneous formations. At Baltalimani and on the hills above Bebek, a ferruginous decomposing trachyte appears in the midst of the schistose rocks. At Kiretch-bornou is a dike of fine-grained greenish trap, about 15 feet in thickness, cutting through strata of calcareous and argillaceous schist. A similar dyke occurs in the limestone quarries at the base of the Giant's Mountain. It is perpendicular, 4 or 5 feet thick, and from the removal of the limestone on each side, it resembles a wall running across the quarry. Some fragments of limestone occur in the midst of the trap, but neither they nor the rock on each side of the dike, show any signs of alteration.

Lower down in the quarry, near the level of the Bosphorus, are some masses of greenish and white quartz rock, which have more the appearance of an altered sandstone than of an igneous injected rock.

3. *Tertiary Formation.*

This formation commences immediately on the west of Constantinople, and extends along the north coast of the sea of Marmora for many miles, its western limit being at present undetermined. On the west side of Constantinople the formation ranges inland for about three miles, till it meets the transition series, but the nature of the junction is not exposed by any section, which I could meet with.

The beds are best exhibited in the quarries at Baloukli and Makri-keui; where they consist of soft white shelly limestones and marls, resting on sand

without fossils. The stratification is in general horizontal, a character common to nearly all the tertiary formations, which I saw in Turkey.

That portion of this deposit which occurs near Constantinople appears to have been accumulated in an estuary. The most abundant shell is an oval, subtriangular bivalve, apparently a Mactra, which composes almost the entire substance of some of the beds; there is also a ribbed bivalve resembling a Cardium. These are apparently the only fossils which belonged to marine genera, all the rest having been natives either of the land or of fresh water.

Potamides, 1 species.
Neritina, 1 species, the delicate black stripes remaining.
Cyclostoma, 1 species.
Helix, a species like H. pomatia.
———, a species resembling H. rufescens.
Bulinus, resembling B. montanus.
———, similar to B. acutus.
Clausilia, 1 species.
Pupa, 1 species.
Planorbis, like P. alba.
Cypris, 1 species.

The terrestrial shells are remarkable for their near approach to existing forms. They are less generally diffused than the marine and fresh-water species, but are abundant in the quarries at Makri-keui.

A single specimen of a bone occurred in this formation, but it is too imperfect for me to decide, whether it belongs to a mammifer or to a reptile.

I found no traces of a tertiary deposit along the banks of the Bosphorus, whence it may be inferred that this channel has been opened at a comparatively late period. Tertiary beds are said to exist along the shores of the Euxine; and lignite has been worked for fuel at Domouz-deri, a few miles west of the Bosphorus.

4. *Ancient Alluvium.*

A few miles north of Constantinople are some extensive deposits of clay, sand, and gravel, reposing on the Silurian schist. The latter formation is barren and devoid of trees, but the alluvial clay favours the growth of the oak and causes the forest of Belgrade. These deposits are of great thickness and consist chiefly of ferruginous clay, with pebbles and bowlders of quartzose and sandstone rocks interspersed. The general want of stratification and the rounded form of the bowlders, denote an aqueous action of considerable violence. These accumulations of detritus appear to skirt the southern side of the Lesser Balcan range towards the N.W.

Taken as a whole, the deposits bear a close analogy to those which in England have been called diluvium; and they appear to have resulted from causes acting on a greater scale than any of those, which produced the local alluvia, noticed by me in Asia Minor.

November, 1836.

XXX.—*On the Geology of the Neighbourhood of Smyrna.*

By HUGH EDWIN STRICKLAND, Esq., F.G.S.

[Read April 5th, 1837.]

THE vicinity of Smyrna presents geological phænomena of considerable interest, and of a more complicated kind than is usual in Asia Minor. A residence there during the winter of 1835-36 enabled Mr. Hamilton and myself to investigate this district with greater attention, than we could bestow upon the other parts of Asia Minor, which we visited; and its geology may, therefore, deserve to be laid before the Society in a separate communication.

The details of the paper can be understood only by reference to the accompanying map, Pl. XXXII., and by a general description of the geographical features of the district.

The Bay of Smyrna and the alluvial plain at its upper end lie between two parallel ridges of high land, ranging from east to west. That on the north commences with the lofty hill of Sipylus, rising abruptly from the plain of Sardis; and this ridge, which separates the waters of the Hermus from the Bay of Smyrna, terminates at Menimen near the estuary of that river, the western part being known by the name of Cordileon. Its total length is about thirty-two miles.

The ridge on the south side of Smyrna Bay, begins with Mount Tartali, the ancient Mastusia, which is the western termination of the Tmolus range. Descending towards the west it passes into the table-land which overhangs Smyrna on the south. Further west the country again rises and forms the group of conical mountains, anciently called Corax, which terminates at the Isthmus of Vourla. The distance from Mount Tartali to Vourla is about twenty-four miles.

These two lofty ranges are united at the Pass of Cavakluderé by a transverse ridge, which separates the Vale of Nimphi from that of Smyrna, and completely isolates the latter.

The rocks in the vicinity of Smyrna belong to the following formations:—

1. Micaceous schist and marble.
2. Hippurite limestone and greenish schist.
3. Tertiary lacustrine limestone and marl.
4. Trachytic rocks.

The general features of these and the other formations of Asia Minor were explained in a paper laid before the Society on November 2, 1836*.

In the Smyrna district, the mountains of the hippurite limestone formation apparently once contributed to form the boundary of a great lake, in which calcareous matter was deposited to the depth of many hundred feet. Two vast eruptions of igneous matter have since taken place, one on the north, the other on the south of the present Bay of Smyrna. These convulsions produced great changes in the form of the surface, and in the arrangement of pre-existing rocks, and the study of this district is thus rendered both interesting and difficult.

As the phænomena exhibited on the north of the Bay of Smyrna are not visibly connected with those on the south side, it will be best to consider each portion of the district separately. I will begin with the southern side, and take the formations in the order of age.

1. The micaceous schist and saccharine marble, which compose the ridge of Mount Tmolus, terminate near the village of Trianda, and form part of the eastern boundary of the lacustrine formation. The micaceous schists of Asia Minor being fully described in the memoir before alluded to, it is needless to repeat their characters in this paper.

2. The compact gray limestone with Hippurites is, in this district, associated with an abundance of compact sandstone and schist, of black, greenish, or cream-coloured hues. The whole formation has been so greatly disturbed, that it is difficult to determine, whether the sandstone and schists were deposited above or beneath the limestone; but their union with it is too intimate to admit of their being regarded as a distinct formation. They seem analogous to the greenish sandstones of the Morea and the *macignos* of Tuscany and Trieste, all of which have been referred to the cretaceous system.

The western boundary of the hippurite limestone of Mount Tartali is at the village of Cucklujah, whence it extends eastward for perhaps fifteen or twenty miles, along the northern declivity of Mount Tmolus. Further details respecting it at this locality will be found in the memoir alluded to.

The range of Mount Corax consists almost entirely of sandstones and shales, but at one point, about $3\frac{1}{2}$ miles west of Smyrna, a small mass of gray limestone is exposed, and serves to identify these rocks with those of Mount Tartali.

Around the village of Baltchikeui the shales are of a pale cream colour, soft and friable, and contain a considerable admixture of sand, which is sometimes so coarse as to become a conglomerate of fragments of quartz, a quarter of an inch in diameter.

* See Proceedings of the Ge o logical Society, vol. ii. p. 423.

About 1½ mile beyond Baltchikeui is a thermal spring, on the site of a temple to Apollo mentioned by Strabo. In the ravine immediately above it, the beds of shale are dark-coloured and compact, dipping thirty or forty degrees to the northward*.

3. Tertiary lacustrine limestone.

This deposit forms an extensive table-land, ranging southward from Smyrna for about fifteen miles. On the east it abuts unconformably against the hippurite limestone of Tartali and the micaceous schist of Tmolus, and on the west it is bordered by the range of Mount Corax. The southern boundary is near Trianda, where the formation rises above the alluvial plain of Tourbali; but the original barriers of the lake on that side are not now apparent. This area is occupied principally by white or yellowish limestone, varying in texture from lithographic stone to soft chalk. The more compact beds closely resemble the secondary limestones of the Ionian Islands, and like them contain nodules and layers of black flint and quartz resinite. From this resemblance we were at first inclined to refer the compact limestone near Smyrna to the secondary series, but after a close search Mr. Hamilton and myself succeeded in finding lacustrine shells (see p. 402) which indicate a tertiary epoch. The flints and quartz resinite exhibit an analogy to those in the lacustrine deposits of Auvergne and of the Cantal, as described by Mr. Lyell and Mr. Murchison†.

White and greenish marls are often interstratified with the limestone, and are most abundant in the central parts of the area between Boudjáh and Sedikeui. About two miles north-east of the latter place the marls contain traces of vegetable remains, and are accompanied by extensive beds of gravel, which both alternate with and overlie them. These gravel beds much resemble the ancient drift or alluvium of England, but are merely a local portion of the lacustrine deposit. They contain rolled pebbles of nummulitic limestone and schist, derived from the surrounding mountains, also fragments of red trachyte similar to that which occurs, *en masse*, near Smyrna.

As is usual with the lacustrine basins of Asia Minor, the beds of limestone and marl pass into conglomerate as they approach the foot of the surrounding mountains. The southern boundary of this formation near Trianda consists almost wholly of gravel imbedded in yellow clay.

The pebbles of trachyte, in the central parts of the formation, appear to prove that, at this point, the lacustrine deposits were continued after the eruption of trachyte, which overlies them near Smyrna. The bed of the lake being probably lowest in the centre, water might lodge there, after the main body

* The author of "Sketches of Turkey" calls them limestone rocks, but on the application of acid not the slightest effervescence takes place.

† Annales des Sciences Naturelles, 1828.

of the lake had been drained by the igneous eruption; and streams flowing from all sides would carry to this point the pebbles which, during the quiescent state of the lake, formed a shingle beach around its margin. In course of time the denudation of the outlet would complete the work of desiccation, and the whole drainage, of what is now the Plain of Sedikeui, would reach the sea by the ravine at present traversed by the Meles. That all these operations have taken place, will, I think, be evident to any one, who will make a careful survey of the locality.

The stratification of the lacustrine series is, in general, nearly horizontal; some local exceptions, however, exist in the vicinity of the igneous rocks.

4. Trachytic rocks.

The greater part of the lacustrine series had been deposited, when the basin of Smyrna became the seat of volcanic action; and an enormous mass of trachytic matter was poured forth, and spread over the bed of the lake. The eruption appears to have ceased as suddenly as it began, for there are no alternations of trachytic and lacustrine rocks,—no injection of dykes, or other phænomena, which indicate a long continuance of igneous action.

These rocks occupy a surface of about five miles by two, and a reddish-brown, porphyritic variety prevails throughout nearly the whole area. A remarkable feature in the trachyte is the close approach, which it occasionally makes to a stratified structure. It splits into slabs from a foot to an inch in thickness, and their cross section exhibits stripes of various colours, parallel to the planes of cleavage. These strata (if they may be so called) are in some places accumulated to the thickness of one hundred feet, and are traceable laterally for as many yards. This is especially the case on the hills about two miles west of Smyrna. The crystalline texture of this *stratified trachyte* decidedly indicates igneous fusion, and the explanation of this peculiar structure is, therefore, by no means easy. It may, however, be conjectured, that when the fluid trachyte expanded horizontally from the point of eruption, any variations of substance or texture would be drawn out and extended in planes parallel to the horizon, and when cooled would cause coloured stripes and fissures in the rock, in the direction of those planes. It must, however, be observed that the apparent strata are now far removed from the horizontal position, supposing them to have once occupied it.

These trachytic rocks are, in general, homogeneous, but in some places, they contain numerous angular blocks and fragments of black porphyritic trachyte, much harder than the reddish paste in which they are imbedded. This species of conglomerate is well developed, about 2 miles west of Smyrna, in a ravine near the sea.

On the north side the trachytic rocks descend to the shore, but along their

southern border, they overlie the lacustrine limestone and marl of the Plain of Sedikeui. The boundary of the two formations is well defined, the trachyte terminating abruptly, with a steep slope, like the margin of a modern *lava coulée*. A stratum of pumiceous tufa is commonly interposed, between the trachyte and the lacustrine strata. The uppermost bed of the latter is a conglomerate of rounded pebbles of quartz, hippurite limestone, and schist, but *not the least trace of any igneous rock is discoverable in it*. Beneath this bed are calcareous marls, containing Planorbes and other fresh-water shells, and passing downwards into white limestone.

The absence of igneous products in the conglomerate proves the sudden eruption of the trachyte which reposes on it; yet it is possible that this bed of transported pebbles may be connected with that event. Earthquakes preceding the eruption may have caused currents in the lake, which would wash these rolled pebbles from its gravelly margin into its central parts, and terminate that long period of repose, during which the subjacent marls and limestones were deposited.

The highest point attained by the trachyte is about 3 miles S.W. from Smyrna, near the valley which separates these rocks from the Corax range. The view from this eminence proves how much the picturesque and botanical features of a country depend on its geology. On the south is the vast, undulating plain of lacustrine limestone and marl, the greater part of which is cultivated and interspersed with villages. On the west, the decomposing sandstone and shale of Corax form a cluster of conical mountains thickly covered by evergreen shrubs. In the east, the view is terminated by Mount Tartali, where the compact gray hippurite limestone forms crags and precipices, with fir and other trees sparingly scattered among them. Lastly, the trachytic rocks in the foreground produce neither trees nor shrubs, but present innumerable masses of naked rock, jutting through a fine green turf, adapted only for pasturage.

Having now given a general sketch of the sedimentary and volcanic rocks which occur near Smyrna, I will introduce a more detailed account of Mount Pagus, where several of them are brought to view within a very small space. (Plate XXXII., Sec. Nos. 1 and 2.)

The hill anciently called Pagus rises immediately to the south of the modern town of Smyrna. It forms the north-eastern extremity of the mass of trachytic rocks above described; and a deep ravine separates it on the east and south from the *plateau* of lacustrine deposits, whose drainage produces the classic river Meles, which escapes into the sea through this ravine.

The height of Mount Pagus may be estimated at about 500 feet. It is principally composed of trachyte and trachytic conglomerate, which on the

east and south extend from the summit to the bed of the Meles; but along the northern declivity they terminate about half-way down, and repose on strata of the lacustrine series. The uppermost of these freshwater beds is here, as elsewhere, a conglomerate of gray limestone, schist, and quartz, in rolled fragments. It passes downwards into beds of sand which may be traced by means of ravines and sandpits for a depth of more than 100 feet, till the houses of Smyrna preclude further search. At the lowest visible point, the sand contains abundant impressions of leaves; also, though more rarely, imperfect shells of Helix and Unio, which identify it with the lacustrine formation.

It is remarkable that these beds of sand and conglomerate dip about 20° *towards* the trachyte of Mount Pagus, which, having been erupted subsequently to their deposition, might be expected to have heaved them in an opposite direction. They are clearly not *overturned*, because the conglomerate of limestone pebbles is here in its regular position, on the top of the other lacustrine strata.

At the north-eastern side of the hill, the sand is replaced by beds of marl and white limestone containing Planorbes; and above them is the never-failing conglomerate, extending under the trachyte. (See Pl. XXXII., Sec. No. 1.)

A few yards lower down, at the foot of the hill near the Caravan bridge, we come unexpectedly upon a rugged mass of rocks belonging to the hippurite limestone formation. Its whole area does not much exceed an acre, and we must suppose that it has been brought up by some convulsion, connected with the outbursts of trachyte in the vicinity. It consists of friable, marly, cream-coloured shale, similar to that at Baltchikeui, and it contains veins of crystalline carbonate of lime, and some masses of a hard, yellowish, calcareo-siliceous stone. The stratification is very obscure, but as far as it could be determined, it dips towards Mount Pagus, conformably with the lacustrine marls, a few yards higher up. These friable schists are extensively quarried, and when broken small are used in Smyrna for garden walks and terraced roofs. On the east side of the schist are some irregular masses of compact, gray limestone, similar to that which, in Mount Tartali, contains Hippurites; and they identify the whole of these dislocated rocks with that formation.

About half a mile N.E. of this point, is a small, isolated hillock of trachyte, the elevation of which may have caused the otherwise anomalous dip of the lacustrine strata, on the N. and N.E. sides of Mount Pagus. (See Section 1.)

The right bank of the Meles, opposite Mount Pagus, presents an escarpment of the lacustrine formation. (See Section 2.) The trachytic rocks on this side are of small extent, but rise, in one place, about half-way up the south side of the ravine, and appear to abut against the edges of the lacus-

trine strata, which form the upper portion of the hill. The highest stratum exposed, is a compact white limestone, containing, though rarely, a small species of Paludina. A singular substance is also found here, being an aggregate of coarse crystals of carbonate of lime, but too loosely united to constitute saccharine marble*.

Below the limestone containing Paludinæ, strata of marl with calcareous nodules are exposed, till they are obscured by the trachyte below. The only alteration apparent in the lacustrine strata, from their contact with the igneous rock, consists in a greenish colour imparted to the marl, limestone, and accompanying flint or resinite, and not observable at a distance from it.

In descending from this point to the ford through the Meles, a singular mass of conglomerate is found in the midst of the trachyte. It consists of rolled quartz pebbles, imbedded partly in a red and partly in a bright green paste. This mass, which is but a few feet in extent, seems to have been derived from the subjacent lacustrine beds, and caught up by the trachyte. Near this point, the latter rock contains some veins of white chalcedony.

We now proceed to the geology of the north side of Smyrna Bay, where phænomena are exhibited similar to those, which are described above.

The gray limestone of Mount Sipylus seems to have formed part of the northern margin of that ancient lake, which was bounded on the east by Mount Tartali, and on the west by Corax; as lacustrine strata still flank the south side of Mount Sipylus; and they probably once extended across the alluvial plain from Bournabat to Cucklujah. Whether that extensive vale has been formed by denudation or by subsidence is uncertain, but its origin is probably connected with the igneous action, which has convulsed the district.

A vast eruption of trachytic matter, apparently contemporary with that near Smyrna, has on this side also broken up and overlaid the lacustrine deposits. It forms the western half of the Sipylus range, called Cordileon, a mountain whose height may be estimated at about 2000 feet above the sea.

§. 1. The eastern part of Sipylus consists of compact gray limestone, rising precipitously from the plain of the Hermus. Further westward, the limestone is accompanied by black and greenish shales, resembling those of Tartali, before mentioned. The boundary between this formation and the trachytic rocks coincides in general with the ravine, which descends from the lake of Kizghioul to Bournabat, but considerable intermixture of these two rocks occurs along the line of junction.

* Strata of the same substance are seen in ascending by the easternmost road from Smyrna to Boudjah.

§. 2. The lacustrine beds repose against the southern slope of Mount Sipylus, from Djaki-keui, in the Vale of Nimphi, to Bournabat, where they are covered up by the trachytic rocks. The most interesting sections of them are on the west side of the ravine, about half a mile north of Bournabat; and the right bank of the torrent here exhibits the phænomena shown in section 4. A small outburst of red trachyte has heaved up strata of white and greenish marl, containing concretionary masses of brown, hard, crystalline limestone. Some of these masses are thickly perforated with sinuous tubes, and resemble travertin formed around reeds; yet it is doubtful whether the tubes originated in any organic body. Above these strata is a succession of whitish calcareous marls, extending about 200 yards to the northward, and dipping 35° N. In one place, a thin bed of brown clay is interposed, and contains fragments of shells and vegetables.

The upper part of these marly beds affords a rich mine to the student in fossil botany; some of the strata being crowded with leaves and other portions of plants, perfectly preserved. The substance of the leaves commonly remains of a ferruginous colour, and contrasts beautifully with the pale cream-coloured matrix.

The leaves belong to about twelve species of trees; and some of them appear referable to the genera *Laurus*, *Nerium*, *Olea*, *Salix*, *Quercus*, and *Tamarix*, all which still flourish in Asia Minor; but it is yet undetermined, whether any of them are identical with existing species.

These fossil vegetable remains are accompanied by shells of the genera *Cyclas*, *Paludina*, *Planorbis*, and *Cypris*.

Lacustrine marls occupy the west side of the ravine, to the height of perhaps 150 feet above the spot, where the fossil plants occur. Their junction with the overlying igneous rocks affords the following interesting series of beds. (See also Plate XXXII., Section No. 1 and 3.)

1. Brown porphyritic trachyte capping the hill, and continuous with that which forms the mountain of Cordileon.
2. Alternating beds of tufaceous conglomerate and sand, regularly stratified, and resembling the conglomerate of Mount Perier, near Issoïre, in France, except that the trachytic fragments are less rolled—30 or 40 feet.
3. Tufa, with numerous fragments of decomposed pumice, 8 or 10 feet.
4. Beds of rolled pebbles, from the size of an egg downwards, of gray limestone, quartz, and schist, but no igneous substances; and similar to the conglomerate which underlies the trachyte on the south side of Smyrna Bay—20 to 30 feet.
5. White and yellow marls, containing, towards the upper part, *Planorbis*, *Lymnæa*, *Paludina*, and *Cyclas*. They extend downwards to the bed of the torrent.

All the strata, from No. 2 to 5 inclusive, are conformable, and dip about 20° S.W.

§. 3. Trachytic Rocks.—These extend westward from the torrent of Bournabat to the mouth of the Hermus, and compose, as before stated, the whole mountain of Cordileon. The prevailing rock is a reddish brown trachyte, identical with that of Smyrna, and, like it, is occasionally divided into laminæ resembling strata.

The junction of these rocks with the lacustrine beds near Bournabat, is already described. In following up the ravine to the lakes of Kizghioul and Karaghioul, several varieties of trachyte and tufaceous rocks occur along the junction of the hippurite limestone and schist. At the lake of Kizghioul, a branch from the igneous rocks extends to the eastward for some distance. The Section, No. 5., Plate XXXII., is here exposed.

About four miles further west, immediately opposite Smyrna, (see Map) a long, narrow ridge descends the side of Cordileon, and divides the waters of two torrents. The composition of this ridge differs greatly from that of the brown trachyte of the surrounding hills. It consists of decomposing felspar, principally of a white or yellow colour, yet it presents also various shades of red and brown. It has a soapy feel, and would perhaps be a valuable material for pottery. At the upper end of the ridge, near a village, is a steep, broken escarpment, where some dikes of bluish and reddish trachyte penetrate the light-coloured substance, above described.

The soft, decomposing state of this rock has given that smooth, rounded form to the ridge which so strongly contrasts it with the rugged neighbouring hills. Its surface is covered with rounded, erratic bowlders of brown trachyte, probably brought down by the torrents, which now flow on each side of the ridge, at a time when they occupied a higher level.

From an inspection of hand specimens, it would not be easy to decide, whether this white earthy trachyte has been altered since its ejection, or whether it was originally poured forth in a different state from the ordinary brown trachyte. The latter opinion, however, is the most probable, if we consider first, the complete dissimilarity between this rock and those which immediately surround it; and secondly, the manner in which this long ridge descends, like a *coulée*, from the higher parts of Cordileon.

These are the principal phænomena which I noticed on the north side of the Bay of Smyrna; and it will be seen that they present a great analogy to those on the south.

The geological events to be inferred from the facts described in this paper, may be summed up as follows:—

1. An elevation of several mountains, composed of rocks of the cretaceous age.

2. A long and tranquil deposition of lacustrine matter, with shells and vegetables, in a depression between these mountains.

3. A sudden eruption, at two principal points, of igneous matter, which broke up and overlaid the deposits of the lake, and drained the greater part of its waters. It seems to have been preceded by a commotion in the lake, spreading *non-volcanic* pebbles over the bottom.

4. A more or less sudden cessation of the igneous action, proved positively by the homogeneous character of the erupted rocks, and negatively by the general absence of injected dikes, or of alternate *coulées* of trachyte, tufa, &c., such as are seen in Mont D'Or.

5. A continuance of aqueous deposition in the central and lowest point of the lake after the igneous eruption, proved by beds of marl, alternating with gravel, containing trachytic pebbles.

6. The drainage of this remnant of the lake by the denudation of its outlet, now traversed by the Meles.

List of Fossil Shells noticed in the Lacustrine Basin of Smyrna.

Species.	Localities.
1. *Helix*, similar to *H. carthusiana*, Drap.	North side of Mount Pagus.
2. *Planorbis*, similar to *P. alba*.	Ravine above Bournabat. A point about 4 miles S.W. of Smyrna.
3. *Lymnæa*, resembling the recent *L. peregra*	N.E. side of Mount Pagus. Ravine above Bournabat.
4. *Paludina*, a small turrited species, like the recent *P. acuta*	Ravine above Bournabat. N.E. side of Mount Pagus. South side of the Meles, towards Boudjah.
5. *Cyclas*, a small species, like *C. pusilla*	Ravine above Bournabat, in company with vegetable impressions.
6. *Unio*, an ovate species	N. side of Mount Pagus.
7. *Cypris*	Ravine above Bournabat.

The specimens of those fossils, which were obtained, are not sufficiently perfect to warrant a greater degree of precision in their determination. Indeed, fossil fresh-water shells rarely possess characters sufficiently marked to form the basis of accurate specific distinctions.

XXXI.—*On the Geology of the Island of Zante.*

By HUGH EDWIN STRICKLAND, Esq., F.G.S.

[Read November 1st, 1837.]

THE observations detailed in this paper are the result of a few days' residence in the Island of Zante, during which I was enabled to take a general view of its geological features; but a complete survey of this and the other Ionian islands is still to be desired. Such an investigation would be a work of labour, for though there is little variety in the rocks, there is much complexity in their arrangement. The structure of Zante, more simple than that of the other islands, presents an epitome of their component rocks in an almost unbroken succession; and it may, therefore, be selected as a type to which the phænomena of the other islands may be referred.

The geological phænomena of Zante may be arranged under the three heads of, 1. Apennine Limestone; 2. Tertiary Deposits; and 3. Mineral Springs. (See Map, Plate XXXIII.).

1. *Apennine Limestone.*—This is perhaps the most convenient appellation for that deposit of compact white or grayish limestone, which is so largely developed in the south of Europe, and especially on the shores of the Adriatic. It has an uniform character throughout many thousand feet of vertical thickness, and many hundred miles of horizontal extent. The few fossils it contains agree with those of the cretaceous, and in part also of the oolitic series of northern Europe. It constitutes, in Zante, an anticlinal ridge, extending in a N.N.W. and S.S.E. direction along the south-western coast, from Point Skinari to Point Cheri, and this ridge is continued through the island of Cephalonia. Along the eastern side the prevailing dip of the strata is from 30° to 45° to the E.N.E.; west of Point Skinari an opposite dip commences, and continues, with few exceptions, to near Point Cheri, where the strata again dip to the eastward.

The tertiary beds occur only on the east of this ridge. On the west we find a series of cliffs, upwards of 600 feet high and almost perpendicular, the sea-worn caves and fir-clothed crags of which present highly picturesque scenery. This steepness is continued to a great depth beneath the surface of the sea, as is proved by the deep soundings along this coast.

The Apennine limestone, of which these cliffs are composed, is nearly white, and less compact than usual, often resembling the hard chalk of the north of England. No beds of flint were noticed here, though in Corfu they are not unfrequent. Organic remains are by no means abundant, yet Nummulites, fragments of Hippurites, and indistinct traces of other fossils, may frequently be detected by searching.

From its compact, inflexible, and brittle texture, the Apennine limestone generally abounds with faults and fractures, which give rise to numerous caverns, (*catavothra*), subterranean rivers, and thermal and mineral springs. In these respects, no less than in its mineral structure, it presents a close analogy to the Carboniferous Limestone of northern Europe, for which it has often been mistaken by observers, who paid no attention to its fossils.

The frequency and violence of earthquakes in many parts of the south of Europe, may perhaps be accounted for by the unyielding texture of this rock, the vibrations being propagated to much greater distances, than in countries composed of more loosely aggregated or more elastic materials.

In Zante the Apennine limestone presents numerous faults, one or two of which will be alluded to in a subsequent page.

2. *Tertiary Beds.*—These occupy the greater part of the island of Zante. Reposing on the eastern flank of the Apennine limestone, they extend to the coast: they rise also in several detached hills through the alluvial plain which forms the centre of the island. They have evidently yielded to the same disturbing force as the limestone range; and they dip from this rock to the eastward. The upper portion is the counterpart of the beds, described by Mr. Hamilton and myself, as occurring near Lixouri in Cephalonia*. In Zante, they are best displayed in the Castle Hill above the town, and in the cliff which extends thence to the eastern coast. (See Plate XXXIII., Sect. 1.) The upper strata near the Lighthouse consist of a porous, calcareo-arenaceous stone, of a pale yellow colour, and easily worked. Fossils are rare in it, except on the east coast, where one or two of the strata contain numerous casts of Cerithia and other mollusca.

These strata are succeeded by a thick deposit of blue clay and marl, forming the height on which stands the citadel of Zante. The shells found in it are principally *Pectunculus auritus*, Broch., *Buccinum semistriatum*, Broch., and *Natica glaucina*, Lam. All these species occur also in the middle portion of the Lixouri section, but more abundantly, and associated with many others.

The gypseous beds, which at Lixouri succeed the argillaceous strata, are not visible in this part of Zante, but on the south coast they form the com-

* See Geological Proceedings, No. 51, and *postea*.

mencement of a section which carries us much further down in the series than the lowermost beds examined at Lixouri. (Pl. XXXIII., Section 2.) The gypsum also occurs in white and conspicuous patches on the hill at the S.E. extremity of the island. The rest of this hill consists of sand and clay belonging to the upper part of the series; but the beds are much disturbed, and not easily reducible to the regular arrangement seen in Sections 1 and 2.

The uppermost beds in Section 2 consist of gypseous marls and gypsum, sometimes fine-grained and saccharine, but sometimes only a coarse aggregate of selenitic crystals like that at Lixouri. The stratification is occasionally preserved, though in others it appears to have been obliterated by the action of crystallization. Angular fragments of a black marlstone, imbedded in the gypsum, seem to have been derived from strata of stone, broken up by the force of the crystallizing process.

The strata of yellow limestone above the gypsum, exhibited in Section 1, and at Lixouri, clearly belong to the Pliocene epoch, many of their fossils being identical with those of the Subapennine hills. The strata which underlie the gypsum in Section 2, consist of a series of brown sandy clays and marls, but whether they also belong to the Pliocene or to a prior epoch, it is not easy to determine. They extend for about two miles along the coast, and dip about 25° to E.N.E., with a few local interruptions. Fossils are very rare in these beds, and in general they are too much crushed to allow the species to be determined. They were noticed only near the middle of the argillaceous series and near its base. At the former spot are crushed fragments of echini and obscure bivalves; and at the latter, is a bed of indurated bluish marl containing an abundance of the shells of Hyalæa and Creseis, but they are larger than those of the species now living in the Mediterranean (*Hyalæa cornea* and *Creseis spinifera*), and are therefore probably distinct species.

The argillaceous beds are succeeded by yellowish calcareous sandstone and loosely aggregated limestone. A great subsidence appears to have taken place between that point and the range of secondary limestone, about a mile distant. This tract forms the marshy plain of Port Cheri, towards which the tertiary strata dip on both sides. There is consequently no traceable sequence between the argillaceous beds above described and the calcareous strata, which we are now considering. The latter dip about 18° S.W., and extend along the east side of the marsh, forming some hillocks at its upper end. They consist in general of calcareous particles, interspersed occasionally with pebbles of secondary limestone; but some of the beds approach the texture of Portland stone. Minute Foraminifera are abundant in it, and the only other fossils noticed were two species of small Pectens.

These calcareous rocks seem referable to a distinct epoch, and may perhaps eventually prove to be of the Meiocene or even of the Eocene age. The fine-grained limestone, extensively quarried near Lixouri in Cephalonia, belongs probably to this part of the tertiary series.

On the west side of Port Cheri is a low cliff of blue marl and clay, the beds of which abut against the secondary or Apennine limestone, and dip about 18° north-east. The only fossils noticed in it, were a few scales and vertebræ of fish, and a species of Vermiculum, Mont. (Quinqueloculina, D'Orb.)

This small, argillaceous mass has been probably derived from a higher part of the tertiary series, and brought down to its present position by the subsidence, which seems to have formed the valley and bay of Port Cheri. Of this depression, there is further proof in a remarkable fault, which occurs in the Apennine limestone, and is marked by a smooth surface of the rock descending to the sea. It may be traced inland in a direction W.N.W. for half a mile or more, rising like a wall above the downcast portion on the north-east side. At the point where it joins the sea the surface is nearly a plane, inclined about 55°. It is scored with numerous striæ, inclined at an angle of 65° to the horizon, the dip of the strata being about 25° N.E.

The enormous friction and pressure of the descending mass have imparted to the surface of rock, a remarkable degree of hardness, and a darker colour than usual. This change of character penetrates to the depth of about two or three inches from the surface; the rock below being softer and white, and resembling the compact chalk of Yorkshire.

The tertiary beds range from Port Cheri northwards along the foot of the limestone, and reappear on the north shore about two miles beyond the village of Catastari; they are shown in Section 3, which is in some respects a counterpart of Section 2, but presents differences which it is not easy to explain. The porous yellow limestone, which at Port Cheri intervenes between the argillaceous beds and the secondary rocks, is here wholly absent, and the tertiary clay appears to pass gradually into the secondary limestone. The highest beds in the section, consisting of blue marl with shells of Creseis and Hyalæa, are the precise equivalents of that which contains these fossils near Port Cheri; and we are thus furnished with a common point of departure in our comparison of Sections 2 and 3. They are succeeded (Section 3) by numerous beds of blue clay and marl, apparently destitute of fossils, becoming more calcareous in the lower part, and ultimately passing into a white limestone resembling hard chalk. A stratum of conglomerate, used for millstones, occurs here, and consists of rolled pebbles of compact Apennine limestone; beneath this are other strata of compact limestone, undistinguishable from that

of the secondary mountain range. The beds above described are conformable throughout, and seem to pass downwards into the secondary limestone; whether this is really the case, cannot, however, be determined from the section before us, for the sequence is again interrupted by an extensive fault, (seen at the left hand of Section 3). It is therefore possible, that the limestone beds below the conglomerate may be considerably above the true base of the tertiary series, and that an *hiatus* may exist between them and the real secondary limestone, which they so much resemble. A careful survey of the line of junction between the secondary and tertiary formations throughout the island, would perhaps solve the difficulties, presented by this section.

§ 3. *Mineral Springs.*—The springs of bitumen, for which Zante has been celebrated from the time of Herodotus, rise in the marsh at Port Cheri, (see Pl. XXXIII., Section 2.). The principal one is a well about five feet deep; the bitumen oozing up from the bottom; and above it the well is filled by clear, cool, and tasteless water, which is probably only an accidental accompaniment of the bitumen. Some travellers (Walsh, Chandler, &c.,) state that bubbles of gas are given out by the bitumen, but in two visits which I made to the spot, nothing of the kind was observed. The produce has been stated at forty barrels annually*. Bitumen also rises in the Bay of Cheri, some hundred yards from the shore. (See Map.) This circumstance proves, that the bitumen is not derived from the peaty soil of the marshy plain, and there is nothing in the composition of the rocks around, to induce us to refer its origin to them; we must therefore suppose, that this substance is derived from that region of volcanic action, which may be almost demonstrated to underlie the Ionian Islands. This supposition derives farther probability from the fact before noticed, that the spot, where the bitumen rises, has been the site of a vast dislocation.

On the northern coast is another remarkable mineral spring, which seems to have escaped the notice of previous observers. It occurs about half a mile to the north of the junction of the tertiary and secondary rocks shown at the left hand of Section 3, Pl. XXXIII. The Apennine limestone here forms a low cliff descending abruptly to the sea. A spring of turbid water, resembling diluted milk, gushes out at the foot of the cliff beneath the sea level, and rising to the surface, from its less specific gravity, flows away above the sea-water in a stratum a few inches thick; flakes of a slimy white substance (probably Glairine) abound in this water, and are seen in the surrounding sea for a considerable distance; a strong smell of sulphuretted hydrogen is diffused

* For further details relative to the "tar-springs," see Hawkins in Walpole's Travels in the East, Chandler's Travels, vol. ii. ch. 79, &c.

around, but no bubbles of gas rose in the water, nor was there any appearance of inflammable gas, on the application of a lighted taper.

On the 30th of May, 1836, the temperature of the air in the shade being 82° Fahr., of the adjoining sea at the surface 73°, and at the bottom in 4 fathoms, 69°, the spring indicated a temperature of 65°. This is so near the mean temperature of the latitude of Zante, that the mineral spring cannot be regarded as thermal. A bottle of the water is now in my possession, but I have not yet ascertained its chemical ingredients; from its close resemblance, however, to the mineral waters of many volcanic regions, as those of the "Aquæ Albulæ" near Rome, we must refer its origin to some analogous cause. Of this we have a further proof in the fact, that this spring rises on the line of a considerable fault which has affected the Apennine limestone at right angles to its strike. The upcast is on the south, and presents a smooth and almost polished surface of rock, rising like a wall at an angle of about 80°, and running in a straight line for about a quarter of a mile inland. (See the Plan, Pl. XXXIII.) It projects some distance into the sea, and the spring above described rises in a recess a few yards to the south. Two smaller springs of similar turbid water issue at the base of the smooth face of rock. There can be little doubt, that the outburst of these springs is owing to this fault, which has opened a passage from the abyss in which they originate.

We have, then, in this mineral spring, an additional indication of the existence of a region of volcanic action, at some vast depth beneath the Ionian Islands,—of which there is already much presumptive evidence in the springs of bitumen, the frequent earthquakes, and, above all, in the current of sea-water absorbed into a chasm in the neighbouring island of Cephalonia*. It is, however, somewhat remarkable that no rocks of igneous origin exist, as far as is known, throughout these islands.

I cannot conclude this imperfect contribution to the geology of the Ionian Islands, without expressing a wish that some competent geologist would undertake an accurate survey of them. Such an undertaking would be well worthy the attention of our Government, and would form an important appendix to the splendid survey, which has been already effected by the French Government in the Morea.

* See Geological Proceedings, vol. ii., pp. 220. 393.

XXXII.—*Letter from* Mr. James de Carle Sowerby *to the Secretary, on the Genus Crioceratites and on Scaphites Gigas.*

[Read March 8th, 1837.]

Dear Sir,

THE recent discovery in the Isle of Wight, by Mr. Bowerbank, of a fossil shell resembling *Ammonites*, but differing essentially from that genus, and of a magnificent *Scaphites*, appears to me of sufficient importance to be laid before the Geological Society; I have, therefore, drawn up the following descriptions, accompanied by reduced figures of the fossils*. Pl. XXXIV.

Crioceratites.

Generic Characters.—An involuted chambered shell, with sinuated septa; the whorls free, sometimes very distant. Siphon in the external margin of the septum.

The genus is distinguished from *Ammonites* by the whorls not uniting or closing upon one another, or making even an impression, except towards the centre of the disc, and not there in all species. From *Scaphites* it also differs in not having the last whorl produced and bent like a hook; this whorl is often marked differently from those which precede it in both genera.

Many of the shells to be grouped in this genus have hitherto been considered *Hamites*. The species to which I allude are *Hamites Beanii*, *H. plicatilis*, and *H. intermedius*†, of Phillips (Geol. Yorks., Pt. I, Pl. 1., figs. 28, 29, 22.), *Hamites rotundus*, (Min. Con., Pl. 61.), *H. spinulosus*, *H. spiniger*, *H. tuberculatus*, *H. nodosus*, and *H. turgidus*, of Mineral Conchology (Pl. 216.).

* These fossils I was induced to consider as belonging to an undescribed genus, for which I proposed, in my communication to the Society, the name of *Tropæum*: since that notice was read, I have seen in the second part of the second volume of Memoirs of the Geological Society of France, published in March, 1837, M. le Ch. Léveillé's description of his new genus *Crioceratites*, which proves to be identical with *Tropæum*. As M. Léveillé's paper must have been read before my letter, it is clear that the name *Crioceratites* must be employed in place of *Tropæum*, and it is a very good name. The circumstance of a foreign author having distinguished the genus goes far to prove the propriety of its being established. Two of Léveillé's species occur in the Speeton Clay of Yorkshire. One of them, *C. Emeritii* (Loc. Cita. Pl. XXIII., f. 1.), is *Hamites Beanii*, of Phillips, Pl. I., f. 28, the other, *C. Honoratii* (Loc. Cita. Pl. XXII., f. 2), is not yet published by any English author, but has been called *H. plicatilis*, although distinct from the species so named in the Mineral Conchology (Pl. 234.).—Dec. 1837.

† I strongly suspect this is not *H. intermedius* of Min. Conch. (Pl. 62.)

If we arrange the genera of concamerated cephalopods, furnished with a siphon, and with sinuated edges to their septa, according to the straightness or degree of curvature of the shell, we shall have them in the following order, beginning with that which has no curve:

Baculites.
Hamites.
Crioceratites.
Scaphites.
Turrilites.
Ammonites.

A similar series may be formed of those which have entire edges to the septa:

Belemnites.
Orthoceras.
Phragmoceras.
Spirula.
Lituites.
Nautilus.

And if we reverse the second of these groups, the genus *Goniatites* will be found a natural link between them. The genus *Crioceratites* fills up between *Hamites* and *Scaphites*, just where it was wanted, parallel to *Spirula**.

The gigantic species from the Isle of Wight I shall name, after its fortunate discoverer,

Crioceratites Bowerbankii, Pl. XXXIV., fig. 1.

Spec. Char.—Whorls about four, slightly flattened on their sides, and nearly close; the inner ones ornamented with numerous radiating furrows, which, gradually disappearing upon the outer whorl, are replaced by eight or ten thick, arched costæ, extending completely across the whorl, and largest and most elevated towards the thinly edged, transversely oblong aperture.

The septa are rather distant, terminating where the costæ begin to enlarge. There is generally a short rib almost close to the aperture, and in one specimen I have noticed an additional short rib between the two long ones which precede the termination. In an individual sixteen inches wide, the septa are one inch and a half apart.

This fossil occurs in the lower green sand on the south coast of the Isle of Wight.

* I have seen the drawing of a fossil found in Devonshire by Mr. Austen, of a form similar to that of *Turrilites*, but with entire edges to the septa; its situation would be between *Lituites* and *Nautilus*.

The *Scaphites* obtained by Mr. Bowerbank is the *Hamites Gigas* of Mineral Conchology, t. 593, which must now be called *Scaphites Gigas*, (see Pl. XXXIV. fig. 2.) The involute portion resembles the inner whorls of the shell just described, but it is upon the straight portion only that the large ribs appear, which moreover have three knobs upon each. This is the third species of large *Scaphites* which has fallen under my notice. I have seen several portions similar to the figure in Mineral Conchology, mostly found near Maidstone, but this is the only specimen showing the involute commencement which I have met with, and I for some time considered it to be an undescribed species.

I remain, dear Sir,

Your obedient servant,

J. D. C. Sowerby.

January 18th, 1837.

PLATE XIX.

Map and Sections illustrative of Capt. Cautley's Memoir on the structure of the Sevâlik Hills, and the Organic Remains found in them: p. 267.

WOOD-CUTS

To illustrate Prof. Sedgwick and Mr. Murchison's paper on a raised beach in Barnstaple or Bideford Bay, on the north-west coast of Devonshire.

General view of the line of coast: p. 279.

Sectional view of the raised beach: p. 286.

PLATES XX. to XXVI.

To illustrate Capt. Grant's Memoir on Cutch: p. 289.

Plate XX.

Map.—This map, drawn to a scale of about 11 miles to an inch, is taken principally from one by Capt. A. Barnes; corrected from other sources, and from my own observations. The geological divisions marked on it do not profess to follow the exact boundaries of each formation, but merely to give in a general view as correct an idea of them as my examination of the country enabled me to do. The blank part, near the upper right-hand corner of the map, shows the portion of the Runn flooded by the Loonee river during the monsoons. The section is intended to give merely an idea of the different ranges of hills, as well as to show the manner in which the surface of the province is occupied by each formation.

Plate XXI.

Plants from the Sandstone and Clay, with beds of coal; and shells from the Upper Secondary Formation: pp. 292, 296.

*Plants described by Mr. J. Morris.**

Ptilophyllum.

Stem — ? Fronds pinnate; pinnæ closely approximated, linear, lanceolate, more or less elongate, imbricate at the base, attached obliquely; base semicircular or rounded; veins equal, slender, parallel.

We have ventured to form these fossils into a distinct genus, conceiving that the circumstances of the oblique insertion of the pinnæ and their overlapping each other at the base, are characters too important to admit of their being united to the genus *Zamites*, to which somewhat similar fossils have hitherto been referred; the *Z. pectinata* of the Fossil Flora belongs to this genus, and a careful revision of the fossil *Cycadeæ* may probably discover other species having this mode of at-

* The plants are stated in p. 294 to consist of ferns and reeds, but when the Memoir was passed through the press the specimens had not been examined by Mr. Morris.

tachment; from the structure of the frond they may, however, be considered to belong to *Cycadeæ*, and to differ from *Zamites* in the oblique insertion of the pinnæ at the base, and from *Coniferæ* by the absence of a primary vein in the pinnæ.

Ptilophyllum acutifolium, t. 21. f. 1 *a*, 2, 3.

Frond pinnate; pinnæ narrow, linear-elongate, acute at the apex.

This species differs from the *Z. pectinata* of the Fossil Flora, in its pinnæ being narrower, longer, and more acute; and more nearly resembles the *Polypodites pecteniformis* of Sternberg.

P. Cutchense, t. 21. f. 4.

Frond pinnate; pinnæ short, scarcely overlapping at the base, apex obtuse.

This specimen has been also referred to the genus from its pinnæ (although wider apart than in the other species) having apparently a rounded base; but the absence of all trace of venation in this fossil must render its correct determination very doubtful. It resembles in form the *Z. Bucklandii* of Sternberg, parts 5 and 6, t. 23, f. 2, or even *Z. taxina* of the Fossil Flora; and it might also be compared to some pinnatifid Polypodiums, as *P. plumula* and *P. taxifolium*.

It is much to be regretted, that more numerous and better-preserved portions of these specimens have not been obtained, so as to compare them more rigidly with the already known forms of fossil vegetation; for it is remarkable the analogy that some of them present to the Stonesfield slate plants.

Lycopodites affinis, t. 21, f. 5.

Stem ——— ? branches linear-elongate, leaves distichous, alternate, ovate-lanceolate, acuminate, adnate at the base.

This specimen has been referred to Lycopodites from its resemblance to the barren portions of *Lycopodium Jussieni* and *L. volubile*.

——— ———, t. 21, f. 1 *b*. f. 6.

These specimens were probably portions of stems belonging either to *Equisetites* or some monocotyledonous plant.

Fucoides dichotomus, t. 21, f. 7.

Frond compressed ? dichotomous; branches unequal, patulate, apex obtusely rounded.

The Shells in this and the following Plates are figured and described by Mr. James de Carl Sowerby.

Fig. 8. *Pholadomya? inornata.* Transversely elongate, ovate, gibbose, concentrically corrugated; beaks very near the anterior extremity; longitudinal ribs very obscure, rounded. Width 1½ inch, length nearly 11 lines.

Loc. near Charee.

Fig. 9. *Pholadomya granosa.* Ovate, subtriangular, gibbose, ornamented with four or five rows of transversely-elongated and but slightly-elevated tubercles; the anterior side nearly straight-flattened, the posterior produced; beaks very prominent. Length 2 inches, width the same.

Loc. near Charee.

Fig. 10. *Pholadomya angulata.* Subtrigonal, gibbose, ornamented with four or five sharp ribs, which are most prominent near the edge; anterior side straight, nearly flat. Length and width equal; in some specimens 2 inches.

Ph. angulata approaches *Ph. Murchisoni* var. of Phillips. (Geol. of Yorks., Pl. VII. f. 9.)

Loc. near Charee.

Fig. 11. *Amphidesma? ovale.* Transversely elongate, ovate, convex, slightly wrinkled, anterior side small, truncated, distinguished from the rest of the shell by a gentle depression; posterior extremity rounded, rather pointed. Length 11 lines, width 1 inch 4 lines.

Loc. near Charee.

There is no proof whatever that either this or the following belong to the genus *Amphidesma*; they are, however, very nearly related to *A. donaciforme* and *A. securiforme* of Phillips.

Fig. 12. *Amphidesma? hians.* Transversely elongated, convex, slightly wrinkled; sides gaping; the anterior small, separated from the rest of the shell by an obscure depression; the posterior rounded, a little flattened. Length 1 inch, width more than $1\frac{3}{4}$ inch: the specimen being broken we have not the measure complete.

Loc. near Charee.

Fig. 13. *Corbula lyrata.* Rounded, triangular, convex, transversely ribbed; ribs about 15, prominent, rounded; posterior side of the larger valve formed into a distinct lobe, convex, nearly smooth—the beak of the same valve much incurved, the margin toothed. Length and breadth nearly equal, sometimes exceeding half an inch.

Occurs grouped in dense masses with *Trigonia Pullus*, a smooth *Uncula*, &c.

Loc. near Charee.

Fig. 14. *Astarte unilateralis.* Transversely obovate, anteriorly truncated, convex, rather flattened and marked with 8 or 9 concentric rugæ near the beaks. Anterior side at right angles with the hinge line; lunette concave, ovate, pointed. Width greater than the length, but variable in proportion, generally about $1\frac{1}{2}$ inch. We have given a view showing the lunette on the right hand.

Loc. near Charee.

Fig. 15. *Astarte pisiformis.* Nearly globose, with pointed beaks; marked with 8 or 9 sharp transverse ridges; edge toothed. Length 3 lines.

Loc. near Charee.

Fig. 16. *Trigonia costata,* var. This shell varies slightly both in form and markings—generally the form is between that of *T. costata,* Parkinson or M. C. t. 85; and *T. elongata,* of M. C. t. 431; which Lamarck, apparently with justice, considers to be but one species.

Loc. near Charee.

Fig. 17. *Trigonia Pullus* (M. C. t. 508, f. 2, 3.)? The markings on the posterior side are not so regular as in the English specimens, but there is no other difference.

Loc. near Charee.

Plate XXII.

(Fossils from the Upper Secondary Formation, Cutch.)

Fig. 1, 2. *Cucullæa virgata.* Transversely elongato-quadrate, with projecting incurved beaks, very convex, marked with many longitudinal irregular, sharp ribs; posterior margin obliquely truncated. Length $1\frac{1}{2}$ inch, width $2\frac{1}{4}$ inches.

Loc. Between Hubbye and Joorun.

Fig. 3. *Nucula tenuistrata.* Obliquely oval, finely striated concentrically; beaks close to the anterior extremity. Length 4 lines, width 5 lines.

Specimens very imperfect, along with *Cucullæa virgata* (fig. 2.).

Loc. Between Hubbye and Joorun.

Fig. 4. *Nucula? cuneiformis.* Transversely elongate-elliptical, gibbose, smooth; beaks close to the anterior extremity, small, incurved. Length 6 lines, width 10 lines.

Loc. near Charee.

Fig. 5, 5 *a. Pecten partitus.* Broad, short-elliptical, depressed, marked with two concave radii, which divide the surface into three parts, both externally and internally, the lateral parts being flattened; concentrically and minutely waved, waves alternately larger and smaller; ears small, nearly equal. Fig. 5 *a.* is a magnified portion of the surface. Length 6 lines, width 5 lines.

Loc. Hubbye Hills.

Fig. 6. *Plicatula pectinoides,* (M. C. t. 409.). If this differ at all from the British species, it is in having rather more the habit of an *Ostrea,* which is apparent in the expansion of the edge.

Loc. near Charee.

Fig. 7. *Exogyra conica,* (M. C. t. 26 and 605.). The few specimens most detached from the matrix appear not to be quite so deep as those figured in the Mineral Conchology.

Loc. Katrore Hills.

Fig. 8. *Ostrea carinata* (Lam. Hist. Nat. VI. 216. M. C. 365.)? The specimens being generally much concealed in the stone or broken, the determination of the species is not possible; the most perfect individuals resemble the young state of *O. carinata,* but that species is so near in some slates to *O. gregaria,* (M. C. t. 111.) and *O. solitaria* (M. C. t. 468.), that fragments cannot be distinguished.

Loc. near Charee.

Fig. 9. *Ostrea Marshii,* (M. C. t. 48.). The *O. Marshii* varies so much in different localities, that we find no difficulty in referring this shell to that species, although the plaits are more numerous than usual.

This specimen is accompanied with an imperfect *Plicatula* (fig. 9 *a.*).

Loc. Katrore Hill.

Fig. 10. *Terebratula intermedia,* (M. C. t. 15, f. 8.) *var.* A small specimen, and rather more deeply plaited than most of the European varieties of the species.

Loc. near Charee.

Fig. 11. *Terebratula biplicata,* (M. C. t. 90 and 437, f. 2, 3.) *var.* A variety of this variable species found in the red chalk at Hunstanton, is precisely similar in form to our specimen, except that it wants the angle on each side of the beak which is here obscurely visible.

Loc. Jooria Hill.

Fig. 12. *Terebratula Sella,* (M. C. t. 437, f. 1.) *var.* A rather longer shell than the British fossil, and deficient in the central plait which most generally occurs in full-grown individuals of that species.

Loc. Pass of the Hubbye Hills.

Fig. 13. *Terebratula concinna,* (M. C. t. 83, f. 6.)? A larger shell than the one figured in M. C. and not so neat, but hardly possessing any character sufficiently strong to mark it as a species; there are, however, rather fewer plaits.

Loc. Jooria Hill.

Fig. 14. *Terebratula nobilis.* Tetrahedral, rounded, sharply plaited; plaits about 16, extending to the beaks, 4 or 6 of them much elevated along the middle of the disk; beaks small, adpressed; sides concave near the beaks.

A large handsome species; when young the general form is depressed, but the middle is even then much elevated. Length and width, each $1\frac{3}{4}$ inch, depth of the valves united, sometimes more than 2 inches.

Loc. near Charee.

Fig. 15. *Terebratula dimidiata,* (M. C. t. 277. f. 5.)? Whether this be *T. dimidiata* or *T. inconstans,* (M. C. t. 277, f. 4.) is a question the specimens are not perfect enough to settle. The flattened form of the specimen figured agrees with that of *T. dimidiata,* but the beaks of our specimens appear too much incurved (perhaps from pressure) and so to approach *T. inconstans.*

Loc. Jooria Hill, and near Charee.

Fig. 16. *Terebratula major.* Transversely obovate, gibbose, plaited; plaits angular, extending to the beaks, about 30, half of them on one side of the front slightly raised; beak of the larger valve prominent, slightly incurved. A larger species than the last, of the same family, well distinguished by its width and even surface. Length, $1\frac{3}{4}$ inch, width $2\frac{1}{4}$ inches, depth of the valves united $1\frac{1}{2}$ inch.

Loc. near Charee.

Plate XXIII.

(Fossils from the Upper Secondary Formation, Cutch.)

Fig. 1, 1 *a. Buccinum pumilum.* Ovate, pointed, transversely striated; spire small; whorls 4, smooth in the middle, slightly convex; aperture ovate, pointed at both extremities. Fig. 1 *a.* is magnified twice. Height 3 lines, diameter 2 lines.

Loc. Mhurr.

Fig. 2. *Belemnites canaliculatus,* Schloth. (Zieten, t. xxi. f. 3.)? The fragments we have of this Belemnite agree well with Zieten's figure of *B. canaliculatus,* which is very probably not distinct from *B. sulcatus* of Miller (Geol. Trans., 2nd Series, vol. ii. part 2, p. 59, Pl. VIII. f. 3.)

Loc. near Charee.

Fig. 3. *Belemnites* ———? A nearly cylindrical fragment without a sulcus. Very like *B. elongatus* of Miller.

Loc. near Charee.

Fig. 4. *Nautilus hexagonus* (M. C. t. 529)? Flatted spheroidal, with a very small umbilicus; front approaching to flat; sides rather conical; septa 15 in a whorl; aperture wider than long; siphuncle unknown. Diameter $3\frac{1}{4}$ inches, thickness $2\frac{1}{4}$ inches, length of the aperture $1\frac{1}{2}$ inch.

This differs from *N. hexagonus* in having a smaller umbilicus and in being more rounded. It wants the line that occurs in the middle of the front of *N. lineatus*, which it nearly resembles. The figure is reduced to half the natural size.

Loc. near Charee.

Fig. 5. *Ammonites Herveyi*, (M. C. t. 195, Zieten, 19. t. xiv. p. 3.) *var.*

This differs from the English specimens only in having a wider umbilicus. It agrees well with Zieten's figure, which differs a little from the English specimens, to which *A. macrocephalus*, figured by the same author at Tab. 5. f. 1 and 4., approaches nearer. The figure is reduced one half.

Loc. near Charee.

Fig. 6. *Ammonites elephantinus.* Approaching to globose, with a very wide umbilicus exposing the inner whorls; whorls obtusely angular at their sides, crossed by very prominent rounded costæ, which divide into two as they pass over the front; aperture transversely elongated, gently arched. Diameter 4 inches, thickness $2\frac{1}{2}$ inches, length of aperture above an inch. The figure is reduced to half the natural size.

Loc. near Charee.

Fig. 7. *Ammonites formosus.* Discoid, with a rounded edge, umbilicate, radiated; umbilicus narrow, acutely conical; radii numerous, slightly elevated, obscure near the umbilicus, often forked near their commencement, passing in a direct course over the front; aperture sagittate, with truncated angles. Diameter 5 inches, thickness $2\frac{1}{4}$ inches, length of aperture $1\frac{1}{2}$ inch. This is reduced in the figure to half its size.

Loc. near Charee.

Fig. 8. *Ammonites lamellosus.* Discoid, thick, with a rounded margin, umbilicate, radiated; umbilicus narrow, exposing a small portion of each inner whorl, smooth; radii numerous, elevated into obtuse lamellæ, commencing with a curve upon the edge of the umbilicus, often forked upon the middle of the sides, bent forward as they pass over the margin. Diameter 4 inches, thickness $1\frac{3}{4}$ inch. The figure is reduced one half.

Loc. near Charee.

Fig. 9. *Ammonites Opis* . . . Discoid, compressed, with an obtuse edge, radiated; inner whorls one-third exposed; whorls slightly convex on their sides, their inner edge rounded; radii commencing with a curve at the inner edge of the whorls, numerous, prominent, rounded, often forked near the middle, slightly bent forward as they pass over the front; aperture elliptical. Diameter $4\frac{1}{4}$ inches, thickness $1\frac{1}{4}$ inch, length of aperture $1\frac{1}{4}$ inch. This figure is also reduced one half.

Loc. near Charee.

Fig. 10. *Ammonites arthriticus.* Discoid, thick, with convex whorls and a rounded margin, tuberculated and ribbed; whorls half-exposed, about 4, their inner margin smooth; tubercles large, near the middle of the sides of the whorls, about 12 in each whorl; ribs prominent, rounded, 3 or 4 from each tubercle and sometimes an intermediate one; aperture nearly circular, completed 3 or 4 times in each whorl with a thickened edge. Diameter $2\frac{1}{2}$ inches, thickness 1 inch. Figured of the natural size.

Loc. near Charee.

Fig. 11. *Ammonites ignobilis.* Discoid, depressed, umbilicated, keeled, radiated; front rounded with a slightly prominent entire keel; umbilicus small, with squarish edges, exposing a small portion of the inner whorls; radii covering half the whorl, in pairs or forked, commencing and terminating with obscure tubercles, waved; aperture sagittate, narrow. Diameter nearly 3 inches, thickness 10 lines. Length of the aperture $1\frac{1}{4}$ inch. Drawn of the natural size.

Loc. near Charee.

Fig. 12. *Ammonites corrugatus* (M. C. t. 451, f. 3.)? An imperfect specimen, rather more strongly ribbed than the one figured in Mineral Conchology. Drawn of the natural size.

Loc. near Charee.

Fig. 13. *Ammonites Armiger.* Discoid, inner volutions exposed; inner whorls radiated and furnished with a row of tubercles on their sides; outer whorl with a row of tubercles near the inner edge, and a row of spines near the outer edge on each side,—the tubercles and spines connected by thick ribs; margin flat; aperture oblong, squarish. Diameter 7 inches. The figure is reduced one-half.

Strongly resembling *A. perarmatus* (M. C. t. 352.), but the whorls increase more rapidly in size, and the aperture is longer. Probably *A. Catena*, *A. perarmatus*, and this are only varieties of one species.

Loc. near Charee.

Fig. 14, 15, 16. *Crinoidal stems*, apparently of 3 species.

Loc. near Charee.

Plate XXIV.

(Fossils from the Nummulitic Limestone and Marl, Cutch, p. 300.)

Fig. 1. *Cardium intermedium.* This shell, of which we have only casts, is very near in form to *Cardita intermedia* of Lamarck; the hinge, as we learn from the impression, however, wants the long marginal tooth, which marks the genus *Cardita*. Length 1 inch, width the same.

Loc. Baboa Hill.

Fig. 2. *Cardium ambiguum.* The furrows upon the surface of this cast are deeper than they would be in a cast from the European *C. serratum*; which, in the general form of the shell and number of furrows it resembles more strongly than it does the *C. lævigatum* of the Indian Seas. Length 2 inches 1 line, width 1 inch 10 lines. Drawn two-thirds of the natural size.

Loc. Baboa Hill.

Fig. 3. *Arca hybrida.* Transversely oblong, oblique, longitudinally costated; costæ strongly marked with the lines of growth,—those on the anterior side, furrowed along the middle; area narrow. Length 11 lines, width 14 lines.

Nearly related to the recent *A. rhombea*, but with a narrower area between the beaks, approaching to *A. Indica* of Linnæus.

Loc. Baboa Hill.

Fig. 4. *Pectunculus Pecten.* Orbicular, convex, ribbed; ribs about 30, radiating, crenated by the lines of growth; hinge-line short. Length 10 lines, width 11 lines.

Very nearly like *P. pectinatus* of Lamarck, but with more numerous and more distinctly granulated rays.

Loc. Baboa Hill.

Fig. 5. *Nucula Baboensis.* Transversely oval, convex, smooth?; lunette sunk; beaks nearest the anterior side. Length $\frac{3}{4}$ inch, width 1 inch.

Nearly resembling *N. Bowerbankii* (Geol. Trans. 2nd series. Vol. v. 136. Pl. 8. f. 11.) but not truncated or pointed below the lunette.

Loc. Baboa Hill.

Fig. 6. *Pecten lævi-costatus.* Short, smooth, radiated; radii about 20, large, equal to the spaces between them; ears large; inside furrowed. Length 1 inch 4 lines.

Length a little less than the width, but the ears enter so much into the sides that they confine the beaks into a small angle, and make the form appear more transverse than it really is.

Loc.

Fig. 7. *Ostrea callifera.* (Lam. Hist. Nat. Vol. vi. p. 218. Deshayes, Coq. Fossiles des Env. de Paris, Vol. i. 339. Pl. LI., f. 1, 2.)? A very ponderous shell, with only a shallow cavity for the animal. Length $3\frac{1}{2}$ inches, width $2\frac{3}{4}$ inches, thickness of the shell above an inch and a quarter.

The figure is reduced to two-thirds of the natural dimensions.

Loc. Wagé-ké-Pudda.

Fig. 8. *Ostrea orbicularis.* Orbicular, plaited; both valves convex; plaits angular, repeatedly forked; surface imbricated. Length and width about two inches, resembling *O. Flabellulum*, but more regularly and finely striated. See p. 302.

Loc. Luckput.

Fig. 9. *Neritina grandis.* Short-conical, smooth; spire concealed; aperture very large; base convex, its margin rounded. Diameter 3 inches, height $1\frac{1}{2}$ inch. Reduced in the figure to two-thirds the diameter.

This resembles *N. Schmidelliana*, but has a larger aperture in proportion and a less excentric apex; it is also higher. The specimen is little more than a cast, and does not exhibit the edge of the inner lip, but still it shows the attachment of the ligament projecting from the lower surface, and that the aperture occupied more than half the base.

Loc. Wagé-ké-pudda.

Fig. 10. *Globulus obtusus.* Globose, with a very short spire; whorls about 6; aperture ovate-elongated, pointed above; umbilicus open, narrow. Height 1 inch, diameter the same.

The short spire of 5 whorls gives this shell a very blunt aspect.

Loc. Baboa Hill.

Fig. 11. *Turbinellus bulbiformis.* Short-fusiform, smooth; spire pointed; whorls 6, flattened in the middle; aperture narrow, pointed at both ends. Height above 7 inches, diameter 5 inches. Reduced to half its size in the figure.

Resembles *T. Napus*, but has a more elongated spire.

Loc. Wagé-ké-pudda.

Fig. 12. *Cypræa depressa.* Obovate, with a blunt spire and a flattened space across the middle of the back. Length $3\frac{1}{2}$ inches, width 2 inches 7 lines. Drawn one half its size.

This being only a cast, we can give but a very imperfect description.

Loc. Baboa Hill.

Fig. 13, 13 *a. Nummularia acuta.* Depressed, sides conical, decreasing in proportional height by age; when young radiated, when full-grown granulated; volutions and septa numerous; edge sharp. Diameter 5 lines, thickness $1\frac{1}{2}$ line.

Distinguished from most other species of Nummularia by the conical form of the sides. Fig. 13 *a.* is a vertical section magnified.

Loc. Luckput.

Fig. 14, 14 *a. Nummularia obtusa.* Irregularly orbicular, thick, smooth, sides flattened; margin rounded; volutions and septa very numerous. Diameter of the largest individual 10 lines, thickness nearly five lines. Fig. 14 *a.* is part of a vertical section magnified. A remarkably thick species.

Loc. Wagé-ké-pudda.

Fig. 15, 15 *a.* & 15 *b. Lycophris Ephippium.* Orbicular, depressed, curved so as to resemble a saddle, with a gently elevated umbo on each side; margin thick, obtuse, with a narrow waved keel in the middle; grains on the surface small and equal. Diameter $1\frac{1}{2}$ inch, thickness 3 lines.

Fig. 15. A full-grown individual, showing by a break that it is composed of two plates; fig. 15 *a.* a portion of the surface magnified; fig. 15 *b.* a portion of a vertical fractured section, and the inner surface of one of the plates magnified.

Fig. 16, 16 *a.* 16 *b. Lycophris dispansus.* Lenticular, thick, with a very thin, expanded, sharp-edged margin; grains on the surface largest in the centre of the disk. Diameter $\frac{1}{2}$ an inch.

Fig. 16. A group, natural size; fig. 16 *a.* vertical section magnified; fig. 16 *b.* a horizontal section magnified.

These two fossils may possibly be different stages of growth of the same species; for there occur along with them many curved plates which are intermediate in form. The grains on the surface are the projecting extremities of internal columns, not merely granulations in the substance of the fossil, as in some species of Nummularia. The internal structure is totally different from that of Nummularia, as it is only on the inner surfaces of the two plates (fig. 15 *b.*) that any appearance of a spiral or concentric series of cells can be traced. In p. 300 these fossils are assigned to the genus *Orbitolites.*

Loc, Both species very abundant at Baboa Hill and Wagé-ké-pudda.

Fig. 17, 17 *a*. *Fasciolites* (Parkinson) *elliptica*. Elliptical with blunt extremities, bands curved. Length $5\frac{1}{2}$ lines, diameter 3 lines. Fig. 17 *a*. is magnified twice.

Several species of this genus occur in the tertiary formations of Europe, but they are longer in proportion to their thickness.

Loc. Wagé-ké-pudda and Baboa Hill.

The following species of Echinodermata are all reduced in the engraving to half their dimensions.

Fig. 18. *Echinus dubius*. Orbicular, depressed; areæ granulated, concave, and nearly free from grains along the middle; the larger furnished with two rows of tubercles near each side; the lesser with one row on each side; pores of the ambulacra in numerous, arched rows. Diameter about 3 inches, height about $1\frac{1}{4}$ inch.

This has apparently imperfect tubercles, and is much longer than *Cidarites variolaris*, Brongn., which however it much resembles.

Loc. Baboa Hill and Wagé-ké-pudda.

Fig. 19. *Galerites pulvinatus*. Orbicular, depressed, spheroidal, covered with minute tubercles. Ambulacra obscure beneath, crossed by grooves above. Diameter $3\frac{1}{4}$ inches, height 1 inch 10 lines.

A species much like *G. depressus*, Lam., but more convex and ten times the size of it.

Loc. Baboa Hill.

Fig. 20, 20 *a*. *Clypeaster affinis*. (Goldfuss, p. 134, t. 43. f. 6.)? Our specimen appears to be more orbicular than the *C. affinis* of Goldfuss, but it is too imperfect to be determined,—the posterior half being nearly all broken away. Length about $2\frac{1}{4}$ inches, width 2 inches, height 1 inch.

Fig. 20 *a*. is a magnified view of part of the surface.

Loc. Baboa Hill.

Fig. 21, 21 *a*. *Clypeaster varians*. More or less obovate, hemispherical; base slightly concave in the middle; ambulacra elongated; anus transverse. Length $2\frac{1}{8}$ to 3 inches, breadth 2 to $2\frac{1}{2}$ inches, height $1\frac{3}{4}$ to 2 inches.

Fig. 21 *a*. Portion of the surface magnified.

C. Bonei of Munster, (Goldfuss, 131. t. 41. f. 7.) resembles this, but is more depressed, and has a circular anus.

Loc. Baboa Hill and Wagé-ké-pudda.

Fig. 22, 22 *a*. & *b*. *Spatangus obliquatus*. Gibbose; emarginate at the front; behind obovate, rather acuminated, and truncated obliquely upwards. Ambulacra deeply sunk in 3 large and 2 smaller ovate pits; base slightly convex. Length $2\frac{1}{2}$ inches, width 2 inches, height $1\frac{1}{2}$ inch.

Fig. 22 *b*. is a magnified tubercle.

Strongly resembling *S. Bucklandii*, (Goldfuss, 154, t. 47. f. 6.) it is however much larger, and has unequal ambulacra. In this and the allied species with concave ambulacra there is a reticulated band surrounding the ambulacra, which deserves attention. (See fig. 22 *a*.).

Loc. Baboa Hill.

Fig. 23, 23 *a*. *Spatangus acuminatus*. (Goldfuss, 158. t. 49. f. 2.)? Our specimen is not quite so much elevated posteriorly as the figure given by Goldfuss, neither is

it quite so wide; in both these circumstances it approaches to *S. lacunosus*; but it is laterally crushed, which may account for the difference. Length $1\frac{1}{4}$ inch, width nearly the same, height 10 lines. A magnified view of the surface is given at fig. 23 *a*.

Loc. Baboa Hill.

Fig. 24. *Spatangus elongatus.* Elongated, ovate, depressed; front emarginate; base convex; ambulacra concave, with two of the rows of pores nearly central; apex excentric; mouth remote from the margin. Length nearly $2\frac{1}{2}$ inches, width $1\frac{3}{4}$ inch, height 1 inch.

The two posterior ambulacra and the posterior portion of the shell are broken; the description is therefore incomplete.

Loc. Baboa Hill.

Fig. 25, 25 *a*. *Clypeaster oblongus.* (*C. scutiformis*? Lam.) Oblong, subpentagonal, convex above, concave beneath; ambulacra very broad, obtuse. The surface magnified is shown at fig. 25 *a*. Length $2\frac{3}{4}$ inches, breadth above 2 inches, height 7 lines.

The specimen is too much mutilated to show the anus. It is more pentagonal than *C. scutiformis*, to which we have before referred it.

Tertiary Formation. Loc. Between Joongrea and Kotra.

Fig. 26, 26 *a*. *Clypeaster depressus.* Pentagonal, much depressed; ambulacra oval; anus very near the margin. (See fig. 26 *a*.) Length in the oldest individual about 2 inches, breadth rather less, height about $\frac{1}{2}$ inch.

This differs from *C. Laganum* in the position of the anus, which in that species is half-way between the mouth and the margin, in the greater size of the papillæ, and in being much thinner.

Tertiary Formation. Loc. Soomrow.

Plate XXV.

(Fossils from the Tertiary Formations, Cutch.)

Fig. 1. *Serpula ? recta.* An oval, free, slightly-waved shelly tube, which we have provisionally called a *Serpula*, although it is more like the tube of a *Teredo*; but it appears to have been formed in loose sand. Diameter $\frac{5}{8}$ inch.

Loc. near Kotra.

Fig. 2. *Siliquaria Grantii.* Spirally striated; striæ crossed by numerous cracks; fissure composed of a series of oval pores. It differs from the recent *S. anguina* only in the smallness of the pores which form the fissure.

Loc. Borders of the Runn.

Fig. 3. *Balanus sublævis.* Subcylindrical with curved valves, nearly smooth. Operculum? Diameter 1 inch, height 9 lines. Parasitic upon shells.

Loc. Soomrow.

Fig. 4. *Corbula trigonalis.* Trigonal, with the front rounded, gibbose, antiquated; valves nearly equal, posterior side truncated obliquely with a carina upon each valve, and pointed; umbones equal, central. Length 6 lines, width 8 lines; but these proportions vary.

Loc. Borders of the Runn.

Fig. 5. *Corbula rugosa.* (Lam. Vol. v. 497.) This differs from the last in being a much wider shell, with more regular and prominent laminæ upon the surface. Length $2\frac{1}{8}$ lines, width $3\frac{1}{8}$ lines.

Loc. Borders of the Runn.

Fig. 6. *Tellina exarata.* Ovate, compressed, ornamented with many erect concentric laminæ; the posterior extremity pointed, much bent. Length nearly $\frac{3}{4}$ of the width, which is nearly 2 inches.

Strongly resembling *Tellina virgata*, (Lam. Hist. Nat. Vol. v. 52.) but wider and more bent.

We have ventured (contrary to our usual custom) to complete the surface of this shell, although much has been lost from the specimen.

Loc. Soomrow.

Fig. 7. *Venus granosa.* Obovate, truncated, posteriorly convex, ornamented with erect concentric laminæ, crossed by numerous striæ which cut these (near the margin) into rounded grains; lunette broad, pointed, convex; beaks nearest the anterior extremity. Length $1\frac{3}{4}$ inch, width more than 2 inches.

This belongs to the same family of *Venus* as *V. Corbis*, and *V. puerpera*, and is scarcely distinguishable from *V. puerpera*, β. (Lam. Hist. Nat. Vol. v. 585.)

Loc. Soomrow.

Fig. 7.* *Venus cancellata.* Obovate, approaching orbicular, gibbose, ornamented with erect concentric laminæ, and many longitudinal striæ; lunette wide, pointed, convex; beaks nearest the anterior extremity. Length $1\frac{3}{4}$ inch, width 1 inch 11 lines.

This resembles the last, except that it is rounder, with thinner laminæ, which are not cut into round grains.

Loc. Soomrow and Kotra.

Fig. 8. *Venus non-scripta.* Transversely oval, convex, smooth, concentrically undulated; lunette elongated, pointed, concave; beaks nearer the anterior extremity. Length 1 inch 4 lines, width $1\frac{3}{4}$ inch.

A smooth and thin shell, with little of the aspect of a Venus.

Loc. Soomrow.

Fig. 9. *Pullastra? virgata.* Transversely oval, elongated, decorated with smooth concentric ridges; beaks nearest the anterior extremity. Length 13 lines, width 1 inch 7 lines.

Several recent species of *Pullastra* are like this, but no described one appears to be identical with it.

Loc. Soomrow.

Fig. 10. *Cardita intermedia*, (Lam. Hist. Nat., Vol. v. part 1. 23. Brocchi. Vol. ii. 520. t. 12, f. 15.)? This strongly resembles several species of *Venericardia*, Lam.

Loc. Soomrow.

Fig. 11. *Cardium triforme.* Orbicular, ventricose, longitudinally striated; anterior side covered with round granules formed by decussating striæ; the posterior side crossed by oblique sets of reflected ridges. Length and width 1 inch 4 lines.

Somewhat resembling the recent *Cardium æolicum.*

Loc. Soomrow.

Fig. 12. *Arca radiata.* Transversely elongated, oblique, rather convex, radiated; radii elevated, furrowed; beaks almost close, nearest the anterior side. Length 7 lines, width 1 inch.

Loc. Soomrow.

Fig. 13. *Arca tortuosa*? Linn. This is only a fragment, and what there is, seems to differ from the recent *Arca tortuosa* in the degree of curvature.

Loc. Soomrow.

Fig. 14. *Pecten Somrowensis.* Obovate, convex, radiated; radii about 24, squamose, subdivided, in one valve into 3, in the other into 5; ears unequal, striated, and squamose. Length 2 inches 2 lines, width nearly 2 inches.

In form this *Pecten* approaches to *P. varians*, but in the structure of the surface it is like *P. plebeius* of the Crag, and many recent species. We have given a magnified figure of part of the surface of the opposite valve.

Loc. Soomrow.

Fig. 15. *Pecten articulatus.* Orbicular, with pointed beaks, depressed, radiated; radii about 28, simple, rounded, crossed by distant scales; ears large, striated, and squamose. Length in an old specimen about 1 inch 8 lines, width 1 inch 6 lines. We have figured a small specimen.

The radii when the scales are worn off appear jointed.

Loc. Bank of the Runn.

Fig. 16. *Gryphæa globosa*, (M. C. t. 392. *Ostrea vesicularis*, Lam. Hist. Nat. Vol. vi. part 1. p. 219. Cuv. and Brongn. Env. de Paris, 383, t. 3, f. 5. *Podopsis gryphæoides*, Lam. Hist. Nat. Vol. vi. part 1. 195.)

This exactly agrees with old specimens found in the chalk of Norfolk.

Loc. Kotra.

Fig. 17. *Ostrea angulata.* Suborbicular, arched, compressed, plaited; plaits angular, numerous, branched towards the margin; laminæ of increase regular, distant, raised at their edges. Length about $1\frac{1}{3}$ inch, width the same.

Loc. Kotra.

Fig. 18. *Ostrea Flabellulum*, (M. C. t. 253. Lam. Hist. Nat. Vol. vi. part 1. 215. *Chama plicata*, Brander, 84 and 85.). The identity of this oyster with the *O. Flabellulum* of the tertiary formations of Europe is unquestionable.

Loc. Cheeosir.

Fig. 19. *Ostrea tubifera.* Orbicular; laminæ of increase thick, raised into a few large, nearly erect tubes arranged in about 6 rows. Diameter 2 inches.

Loc.

Fig. 20. *Ostrea Lingua.* Much elongated, smooth, approaching to even; upper valve flat or concave, the other very convex; squamoso-fimbriated at the edges. Length $2\frac{1}{2}$ inches, width $1\frac{1}{2}$ inch.

So variable are *Ostreæ* in form and so much do the species resemble each other, that it is hardly possible to define some of them clearly. That before us is very like *O. tenera* (M. C. t. 252, f. 2 and 3.), yet in the depth of the attached valve it approaches to *O. Meadii* (M. C. 252, f. 1 and 4.), but is not waved like that.

Loc. near Joonagrea and Kotra.

Plate XXVI.

(Fossils from the Tertiary Formations, Cutch.)

Fig. 1. *Bulla lignaria*, Linn. This agrees perfectly with the recent species as far as we can ascertain from specimens which are not perfect; but it is quite distinct from both the fossil shells described by Deshayes under the same name.

Loc. Soomrow.

Fig. 2. *Natica obscura.* Globose, umbilicate; spire small, pointed; whorls about 5, convex, flattened, and ornamented at the upper edge with fine diverging plaits; umbilicus partly filled with a semi-cylindrical, obliquely-truncated callus. Height $1\frac{1}{4}$ inch, diameter the same.

Nearly related to *N. Epiglottina*, Lam., but distinguished by the flattened upper margins of the whorls; and to *Nerita canrena* of Brocchi, Vol. ii. 296.

Loc. Soomrow.

Fig. 3. *Natica callosa.* Obliquely depressed; spire small, hardly projecting; umbilicus covered by the thickened and expanded inner lip; aperture very large. Height 2 inches, diameter $1\frac{3}{4}$ inch.

A very distinct species.

Loc. Soomrow.

Fig. 4. *Globulus? anguliferus.* Oblong, obliquely striated; spire produced; whorls about 4, with their sides and upper edges flattened; umbilicus open, rather large. Height and diameter $\frac{3}{4}$ inch.

The elevated lines or striæ advancing towards the aperture as they descend the sides of the whorls form a peculiar character. The aperture appears to be small.

Loc. Borders of the Runn.

Fig. 5. *Solarium affine.* Convex above, flattish beneath, marked with diverging striæ on both sides; whorls 4 or 5, with a deflected entire carina, above which are 4 furrows placed at nearly equal distances, and below, 2 furrows near the carina, and 2 near the umbilicus, which is large, with a crenated edge. Diameter $1\frac{1}{2}$ inch, height $\frac{1}{2}$ inch.

Perfectly distinct from *Solarium perspectivum*, which it somewhat resembles.

Loc. Soomrow.

Fig. 6. *Trochus cognatus.* Conical with straight sides; whorls numerous, ornamented with several rows of granules, which sometimes (especially towards the apex) are united by elevated lines, and a row of tubercles upon the inferior edges of the upper whorls, succeeded by 2 rows upon the middle volutions, and crenated ridges of slight elevation on the rounded border of the lowest whorls; base flat, concentrically furrowed, containing a thick plait within.

Like *T. maculatus*; height 2 inches, diameter of the base nearly the same.

Loc. Soomrow.

Fig. 7. *Turritella angulata.* Turrited, conical; whorls convex, decorated by about 7 carinæ, of which the lowest but one is much the most prominent. Height $1\frac{1}{3}$ inch, diameter 8 lines.

Loc. Soomrow.

Fig. 8. *Turritella assimilis.* Turrited, whorls convex, ornamented with 6 or 7 carinæ, of which 2 or 3 are obscure, the 2nd and 5th being prominent. Height $1\frac{1}{2}$ inch, diameter 5 lines.

A smaller, narrower species than the last.

Loc. Soomrow.

Fig. 9. *Terebra reticulata.* Subulate; sides of the whorls flat, cancellated; a narrow upper portion of each whorl divided from the lower in the form of a band by a ridge and furrow; beak short, curved.

In some specimens the transverse or spiral lines are less conspicuous, particularly on the band and the upper half of the whorl.

Loc. Soomrow.

Fig. 10. *Cerithium rude.* Subulate, with curved sides, ribbed and furrowed; ribs numerous, cut across by about 5 square furrows, of which the uppermost is distant from the suture; whorls 10 or 12, nearly flat, with an obtuse varix between each—the last varix very prominent; aperture nearly round, with a canal at the upper angle; inner lip thick, with a callus at the top; beak broken. Height 2 inches 8 lines, diameter about 8 lines.

Loc. Soomrow.

Fig. 11. *Cerithium corrugatum.* Subulate, ribbed and coarsely striated; ribs numerous, arched, and prominent, crossed by deep striæ; whorls 8 or more, rather convex, with a distinct varix upon each.

This has much of the contour of an elongated Fusus. The lip and beak are wanting in the only specimen found.

Loc. Soomrow.

Fig. 12. *Fusus? granosus.* Short-fusiform, ribbed; ribs about 12 upon each whorl, divided into grains by 6 or 7 transverse ridges, convex; spire half the length of the shell; beak suddenly contracted. Height 4 lines.

A pretty shell, much resembling some species of *Nassa* which occur in the Crag.

Loc. Soomrow.

Fig. 13. *Fusus lævisculus.* Short, fusiform, ribbed, and striated; ribs irregular, mostly very short; whorls 6, angular; base conical; beak short. Height 10 lines, diameter 5 lines.

Loc. Soomrow.

Fig. 14. *Fusus nodulosus.* Fusiform, elongated, ribbed and strongly striated; ribs short, broad, about 8, in the middle of each whorl; whorls 6 or 7, concave above, convex below; beak contracted.

Loc. Soomrow.

Fig. 15. *Fusus* (*Murex*?) *hexagonus.* Short-conical, with an elongated beak, 6-angled; whorls about 6, with 6 ribs on each, which form the angles of the spire, and are crossed by 3 strong ridges upon the spire, thickened where they cross, convex; beak suddenly contracted.

Loc. Soomrow.

Fig. 16. *Ranella Bufo.* Conical, with 2 rows of thin expanded varices and several ribs, the whole crossed by 3 or 4 prominent and several intermediate thin ridges;

whorls 7 or 8, convex; varices obtuse at their edges; aperture oval; beak short, oblique. Height 1 inch 4 lines, diameter 1 inch.

Nearly resembles *Ranella bituberculata* of Lamarck.

Loc. Soomrow.

Fig. 17. *Rostellaria rimosa,* (M. C. 91. f. 4, 5, 6, *Strombus cancellatus,* Lam. Hist. Nat. Vol. vii. t. 212.?)

The fragment we have before us, is firmly imbedded in the stone, and we are not able to clear the lip so as to ascertain whether it be striated like the lip of the recent *Strombus cancellatus,* Lam., or smooth and thickened as in *Rostellaria rimosa* and *R. Fissurella,* Lam., &c.; of all these, the species nearest to the fossil is *R. rimosa* of the London Clay, which is easily distinguished from *R. Fissurella,* Lam., of the Paris Basin, by being striated all over, and having the canal continued nearly to the apex of the spire, but not curved back. From *Strombus cancellatus,* Lam., this fossil is distinguished by having a tumid varix upon the last whorl, a character also of *Rostellaria rimosa,* and we are consequently induced to refer the Cutch shell to it rather than to *Strombus cancellatus.*

Linnæus and his immediate followers did not distinguish between the recent and fossil shells, although the recent one (*Strombus decussatus,* Lam.) has the lip striated within, and is placed by Lamarck in another genus, while Deshayes in the "Coquilles fossiles des environs de Paris," unites the French fossil and the two English ones under one name, although they are perfectly distinct; probably he has not examined English specimens. We find the characters very constant, and easily observed when once pointed out. The analogous shells of Bordeaux are equally distinct. About the same size as *R. rimosa,* M. C., from Barton.

Loc. Soomrow.

Fig. 18. *Rostellaria rectirostris.* (Lam. Hist. Nat. Vol. vii. 192.) The elongated form induces us to refer this fossil to the recent *R. rectirostris,* in preference to any other species.

Loc. Soomrow.

Fig. 19. *Strombus deperditus.* Turbinate, tuberculated, and transversely striated; tubercles united by a slight carina gradually increasing in size; lip thickened, produced above into a short pointed lobe. Height $2\frac{1}{4}$ inches, diameter 1 inch 4 lines including the wing.

Much like *Strombus Gallus,* Linn., and *S. bituberculatus,* Lam., but the tubercles are of an equal size on the last whorl and not much larger than on the spire. The aperture is not much dilated, so that the wing is rather small. It appears to be a very common shell in the Runn, but perhaps there are several species, as many of the specimens are so firmly attached to the stone, and so much concealed, that the distinguishing marks cannot be traced.

Loc. Soomrow.

Fig. 20. *Strombus nodosus.* Turbinate, elongated, tuberculated, transversely and longitudinally striated; tubercles equal, numerous, prominent, obtuse. Height $1\frac{3}{4}$ inches.

Distinguished by the rounded tubercles, of which there are about 12 to each whorl—and the elongated spire.

Rare—we have seen but one specimen and that is very imperfect.

Loc. Soomrow.

Fig. 21. *Cassis* (*Cyprœcassis*, Stutchbury,) *sculpta*. Ovate, transversely sulcated; aperture narrow, the outer lip plaited, the inner smooth. Height $1\frac{3}{4}$ inch, diameter 1 inch.

Strongly resembling *Cassis* (*Cyprœcassis*, Stutchbury,) *Testiculus* (*Bucc. Testiculus*, Linn.), but smoother, and with a narrower aperture.

Loc. Soomrow.

Fig. 22. *Turbinellus affinis*. Subfusiform, swelled in the middle, ornamented with many transverse ridges and a row of flatted tubercles near the upper margin of each whorl; beak produced transversely, ribbed; columella 5-plaited. Height 4 inches, width 2 inches.

Very nearly related to *Turbinellus Scolymus*, Lam., but it is more elongated, has smaller tubercles, and 5 not 3 plaits on the columella.

Loc. Soomrow.

Fig. 23. *Mitra scrobiculata*. (Brocchi, Vol. ii. 317. t. iv. f. 3.)? This is the same as the fossil found at Piacenza. It is often larger than our figure.

Loc. Soomrow.

Fig. 24. *Mitra fusiformis*. Fusiform, pointed, striated; striæ distant, deep, punctated, suture entire; columella with 4 plaits. Height 2 inches, diameter $9\frac{1}{2}$ lines.

Somewhat resembling *Mitra adusta* of Lamarck.

Loc. Soomrow.

Fig. 25. *Volupta jugosa*. Fusiform, pointed, transversely striated, costated; costæ many, rounded, terminating in points above the suture; aperture elliptical, elongated; columella with 3 plaits. Height $2\frac{1}{2}$ inches, diameter $1\frac{1}{4}$ inch.

This differs from *V. Magorum* of Brocchi, in the form of the ribs, and the small number of plaits upon the columella, and from *V. costata*, (M. C. t. 290.) in the form and in the greater number of the ribs.

Loc. Soomrow.

Fig. 26. *Voluta dentata*. Turbinate, striated, spire short, conical, pointed; whorls crowned with tubercles which surround a concave space; aperture elongated; the outer lip thick, crenato-dentated within. Height 1 inch 7 lines, diameter 1 inch.

Loc. Soomrow.

Fig. 27. *Cypræa humerosa*. Obovate, depressed with 3 protuberances upon the back, and one on each side. Length 2 inches, width $1\frac{1}{2}$ inch.

Loc. Soomrow.

Fig. 28. *Cypræa Prunum*. Oval, ventricose; aperture narrow, slightly curved with about 20 teeth on each side; base convex; beak small, not much produced; a very even shell. Length nearly 2 inches, width $1\frac{1}{4}$ inch.

Loc. Eyerau.

Fig. 29. *Cypræa digona*. Ovate, ventricose, slightly depressed; base flattened on each side; beak expanded, prominent, with sharp edges; teeth on each side the aperture, above 20. An obscurely-marked species. Length 13 lines, width $9\frac{1}{2}$ lines.

Loc. Soomrow.

Fig. 30. *Cypræa nasuta.* Ovate-elongated, ventricose; beak projecting, large; posterior extremity of the lip produced; apex of the spire sunk. Length 10 lines, width 6 lines.

Loc. Soomrow.

Fig. 31. *Terebellum obtusum.* Ovate, much elongated; spire 2 or 3 whorls, obtuse. Length about 2 inches, width 6 lines.

This is more like the recent *T. subulatum* than the fossil *T. fusiforme.*

Loc. Soomrow.

Fig. 32. *Oliva Pupa.* Elongated, subcylindrical, with a produced pointed spire, a broad smooth band at the base, and a slightly-plaited callus on the columella. Length 1 inch 9 lines, width 8 lines.

Loc. Soomrow.

Fig. 33. *Conus brevis.* Short-conical; spire flat, with a produced apex marked with 4 concentric striæ decussated by the lines of growth; base ornamented with several small, rather distant ridges. Height $1\frac{1}{4}$ inch, diameter 1 inch.

Imperfect specimens are found, more than double the diameter of the figure.

Loc. Soomrow.

Fig. 34. *Conus militaris.* Conical, elongated, slightly contracted towards the edge of the spire, coloured by many triangular spots arranged in zigzag rows; spire flat, upper surfaces of the volutions concave; base nearly smooth. Height $1\frac{1}{2}$ inch, diameter 11 lines.

This shell and the following retain traces in a remarkable manner of the original colouring.

Loc. Soomrow.

Fig. 35. *Conus catenulatus.* Conical, elongated, coloured with transverse rows of white spots upon a dark ground—spire flat, elevated in the middle, concentrically striated, mottled with white, the edge sharp; the base obscurely furrowed. Length $1\frac{1}{4}$ inch, width 8 lines.

Loc. Soomrow.

Fig. 36. *Conus marginatus.* Conical, much elongated; spire conical, short, surrounded by an obtuse ridge from its base to its apex; base of the shell striated. Length $1\frac{1}{2}$ inch, width 8 lines.

Loc. Soomrow.

WOOD-CUTS.

Section of the elevated plateau of nummulitic limestone on which is situated the town of Luckput: p. 300.

Dyke of basalt intersecting and throwing off the strata of slate-clay and sandstone, in the river near Jaumtra: p. 308.

Bank of the river near Jarra on the borders of the Runn, exhibiting the different effects produced on laminated and compact strata by disturbing forces: p. 309.

Diagram of alternations of Basaltus with Travertin: p. 314.

End view of one of the natural walls of the Runn: p. 321.

Four views of natural walls of the Runn: pp. 322, 323.

Wall of Sandstone near Rampoora, p. 324.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

PLATES XXVII. and XXVIII.

To illustrate Mr. Murchison and Mr. Strickland's Memoir on the Upper Formations of the New Red Sandstone System in Gloucestershire, &c.: p. 331.

Plate XXVII.

Map and Sections: p. 331. et seq.

Plate XXVIII.

(Fossils from the Keuper Sandstein, p. 338.)

Fig. 1. Ripple marks and impressions of footsteps on a slab of sandstone from Shrewley Common, Warwickshire, one-third the natural size. The impressions are in relief. The slab is preserved in the Warwick Museum; but a portion of the counterpart is in the Museum of the Geological Society: p. 339.

The footsteps were formed by an animal which was probably allied to the Batrachians. The toes appear to have been destitute of claws, and the larger or posterior foot exhibits faint traces of having been webbed. In these respects and in their general form they have some resemblance to the feet of frogs, but differ from them in having the outer toe of both the hind and fore feet longest, while in frogs the second toe is the longest. It is moreover evident, that this animal possessed a tail, which dragging in the soft sand, has caused a groove, about $\frac{3}{8}$ of an inch wide, intermediate between the alternate footsteps. This groove meanders slightly from side to side, approaching each pair of footsteps alternately.

The impressions of the feet are repeated twelve times, at equal intervals of about $9\frac{1}{4}$ inches. To this, however, there are two exceptions,—the distance from *a* to *b* in fig. 1. being only 6 inches, and from *c* to *d* 7 inches. We may conjecture that the animal stopped for a time at this point, and then proceeded, an opinion which is confirmed by the semicircular ridge of sand marked *e*, which may have been formed by the under side of the animal, or by the impulse necessary for the resumption of his motion. Several smaller impressions of similar footsteps may be detected on the surface of the slab; four of them marked *f*, *g*, *h*, *i*, are in regular alternate succession; the others, marked *k*, are in no regular order, the impressions corresponding to them being too faint to be detected.

A considerable resemblance exists between these impressions and some which have since been discovered (in company with those of the Cheirotherium) in the Bunter Sandstein at Storeton Hill, near Liverpool; also at Grinshill near Shrewsbury, specimens of which latter are in the Museum of that town.

Fig. 2. A pair of footsteps of the natural size marked with a star on fig. 1.

Fig. 3. An Ichthyodorulite of *Hybodus Keuperi* (Murch. and Strick.) from Burgehill, now in the Museum of the Geological Society.

This Ichthyodorulite was nearly perfect when the description at p. 338 was written, but having been since unfortunately injured, we are able to show only the fibrous structure of the interior in fig. 3, the external costæ on the lower side

being concealed by the matrix. The costæ are however seen on the fragment fig. 3*a*. natural size, and the fibrous internal structure is shown, magnified twice, at fig. 3 *b*. p. 338.

Fig. 3*. A small tooth, probably of a species of Hybodus, from Shrewley Common, natural size and magnified twice. In the Museum of the Geological Society.

Fig. 4. A fragment of sandstone with casts of *Posidonomya minuta*, Bronn, from Shrewley Common. In the Museum of the Geological Society: p. 338.

Fossils from the Bunter Sandstein.

Fig. 5. Maxillary bone of a fish in the Warwick Museum, from a quarry 1 mile N.W. of Coventry. The left-hand end of the figure seems to be the anterior extremity. The bone, which is here thickened and rounded, gradually becomes thin and flat towards the other end. Much of the thinner portion is wanting, but the impression of the lower surface remains in the sandstone, as shown by the dark shade in the figure. The specimen seems to have been considerably worn, and to have lost several of the teeth, before it became imbedded in the sandstone.

Fig. 6. Tooth of Megalosaurus? (*a*) natural size, (*b*) magnified twice. From Coton End near Warwick: p. 344.

Fig. 7. A smaller tooth of the same animal from Coton End. Warwick Museum: p. 344.

Fig. 7*a*. A small tooth from Leamington. Museum of the Geological Society.

Fig. 8. Tooth of a Saurian? from Coton End. Warwick Museum: p. 344.

Fig. 9. A smooth curved tooth, flattened on one side, from Leamington. Warwick Museum.

Fig. 10. A vertebra from Coton End. Warwick Museum: p. 344.

Fig. 11. *Echinostachys oblongus* from Hadley near Ombersley, Museum of the Geological Society: p. 340.

WOOD-CUT: p. 348.

Fragment of sandstone from Berkswell.

PLATES XXIX. and XXX.

Illustrate Dr. Riley and Mr. Stutchbury's paper on Saurian remains from the Magnesian Conglomerate near Bristol: p. 349.

Plate XXIX.

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Fig. 3. Fragment of a jaw, exhibiting the alveolary septa and a young tooth: p. 351.

Fig. 4 and 5. Teeth of *Paleosaurus cylindrodon* and *P. platyodon*: p. 352.

Fig. 6, 7 and 8. Vertebræ, natural size: p. 352.
Fig. 9. Chevron bone, natural size: p. 353.
Fig. 10. Rib, natural size: p. 353.
Fig. 11. Fragment of a coracoid: p. 354.
Fig. A. represents part of the dental bone of *Saurodon lanciformis*, magnified three times; fig. B. portion of the upper jaw and detached teeth of *Saurodon Leanus*. They are both taken from the plate which illustrates Dr. Hay's Memoir on the Saurodon. Amer. Phil. Trans., New Series, Vol. iii. p. 471. Pl. XVI.

Plate XXX.: p. 354.

Fig. 1 to 6 reduced to one-half, *Fig.* 7 to 12, natural size.
Fig. 1, 1*a*. Humerus: p. 354. *Fig.* 2. Radius: p. 354.
Fig. 3, 4, 4*a*. Femurs: p. 355. *Fig.* 5. An Ichium: p. 355.
Fig. 6. A Tibia: p. 356. *Fig.* 7, 7*a*. A Fibula: p. 356.
Fig. 8 to 13. Metacarpal or Metatarsal bones and uncial Phalanges: p. 356.

PLATE XXXI.

Illustrates the Rev. W. B. Clarke's paper on the Geological Structure and Phænomena of the county of Suffolk, &c.: p. 359.

WOOD-CUTS

To illustrate Mr. Strickland's paper on the Geology of the Thracian Bosphorus: p. 385.

Section from Constantinople to Symplegades: p. 385.

Section of a conglomerate near Filbornou, consisting of angular fragments of trachyte, imbedded in a tufaceous paste and traversed by veins of calcedony: p. 389.

Section on the north side of Anadoli-fanar: p. 392.

PLATE XXXII.

Map and Sections to illustrate Mr. Strickland's Memoir on the Geology of the neighbourhood of Smyrna: p. 390.

PLATE XXXIII.

Map and Sections illustrative of Mr. Strickland's paper on the Geology of Zante: p. 403.

PLATE XXXIV.

To illustrate Mr. James de Carl Sowerby's paper on *Crioceratites Bowerbankii* and *Scaphites gigas*: p. 409.
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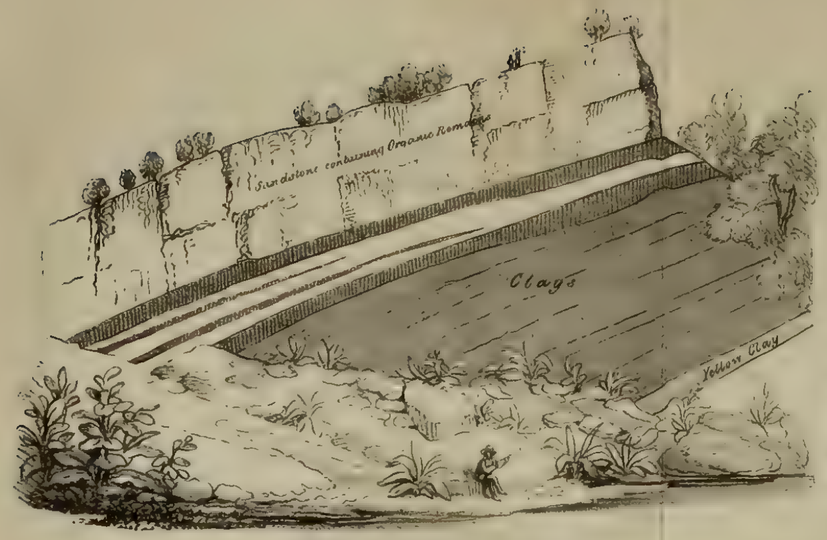
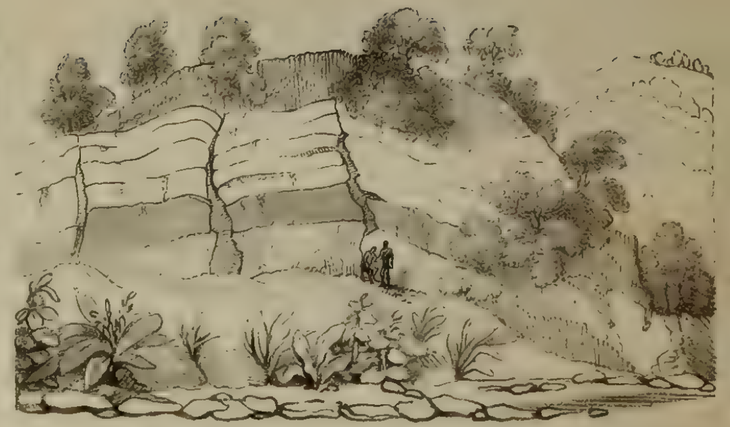
Fig. 2. *Scaphites gigas*: p. 411.

Part of the Country
between the
SUTLUJ and the RAMGUNGA

To illustrate Cap! Cautleys memoir on the organic remains found in the Sevâlik Hills.
p 267



SLIP under TULOAGPOOR



DISLOCATION of STRATA below the Village of TULOAGPOOR

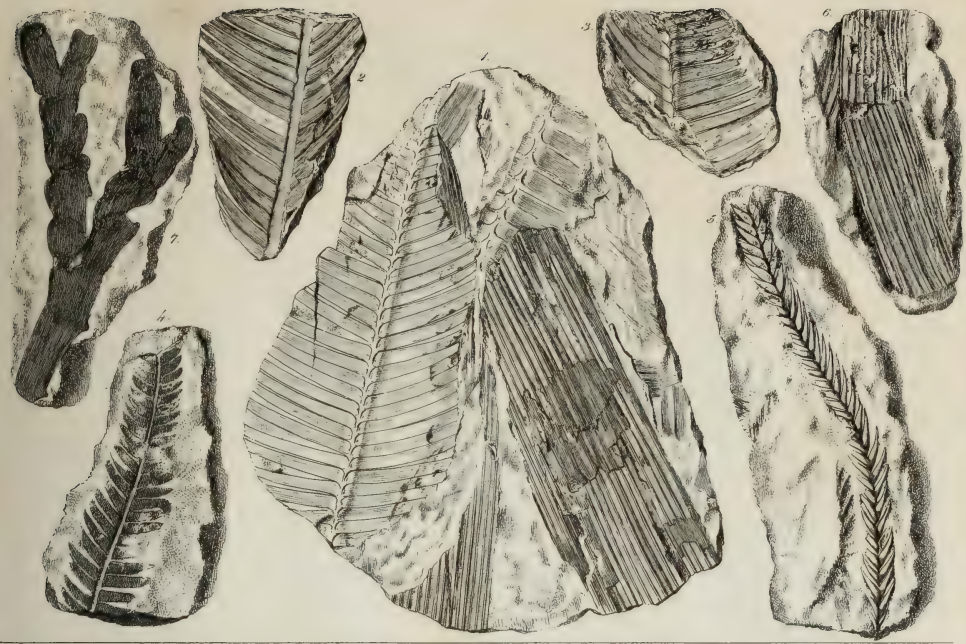
PLATEAU near the Village of Jabree, MURKUNDA RIVER

PLATEAU upon which the Village of DEONI is situated, MURKUNDA RIVER

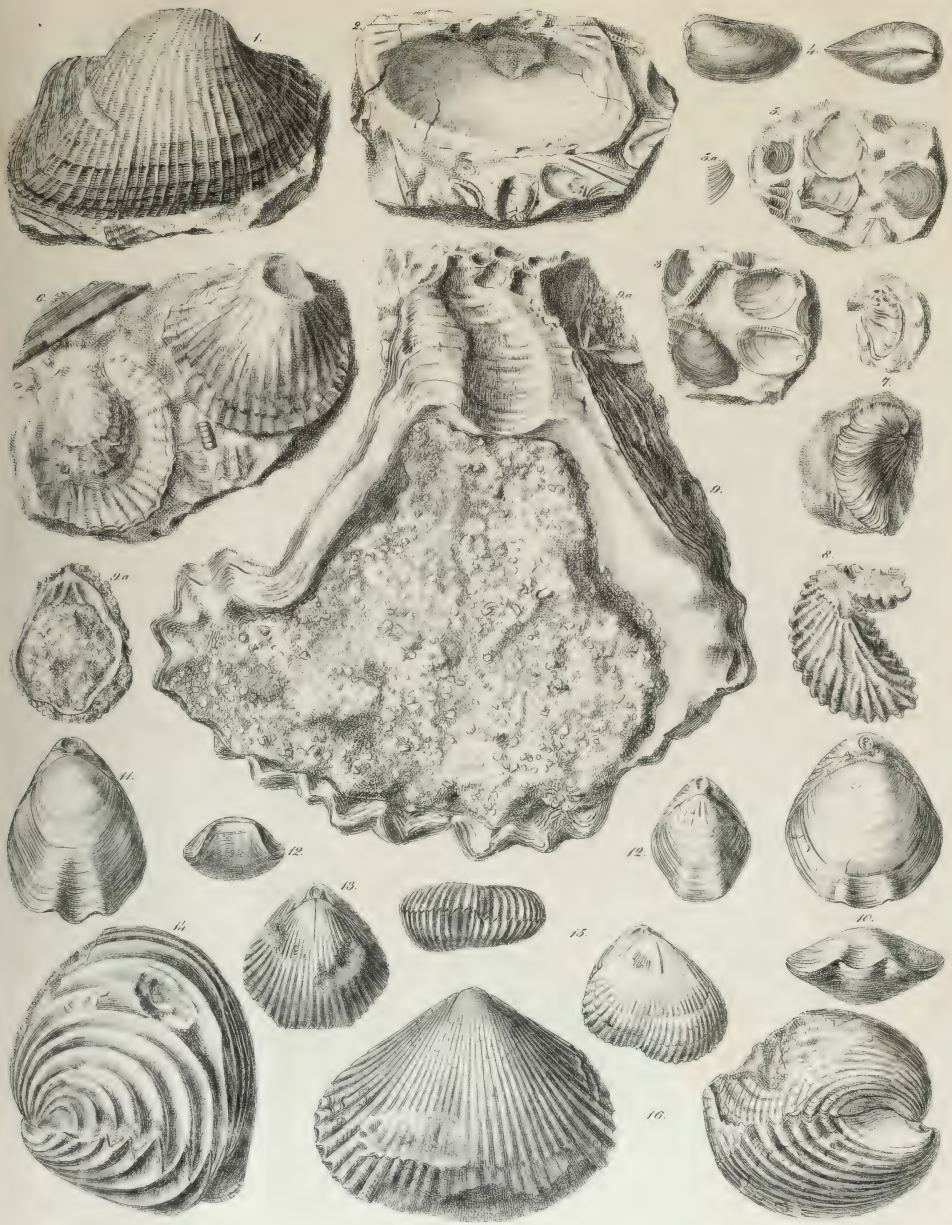
S I N D E
The Thurr or Little Desert
Parkur
Ullah Bund
Thrown up by the Earthquake of 1819
Covered with water since the Earthquake of 1819
Sindree
THE GRAND RUNN
Pucham Isle
Khureer Isle
THE BUNNEE
KATTYWAR
RUNN
GULF OF CUTCH
Kattywar
CUTCH
shewing the
GEOLOGICAL DIVISIONS.
Syenite
Sandstone & Clay with Coal
Laminated Series or Up. Secondary
Nummulitic Group
Tertiary
Alluvial or Recent
Volcanic & Trappean Rocks
C. W. GRANT, Capt. Bombay Engineers
1836

SECONDARY FOSSILS.

CUTCH.



SECONDARY FOSSILS.
CUTCH.



1a.
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3.
4. ½
5. ½
6. ½
7. ½
8. ½
9. ½
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12.
13. ½
14.
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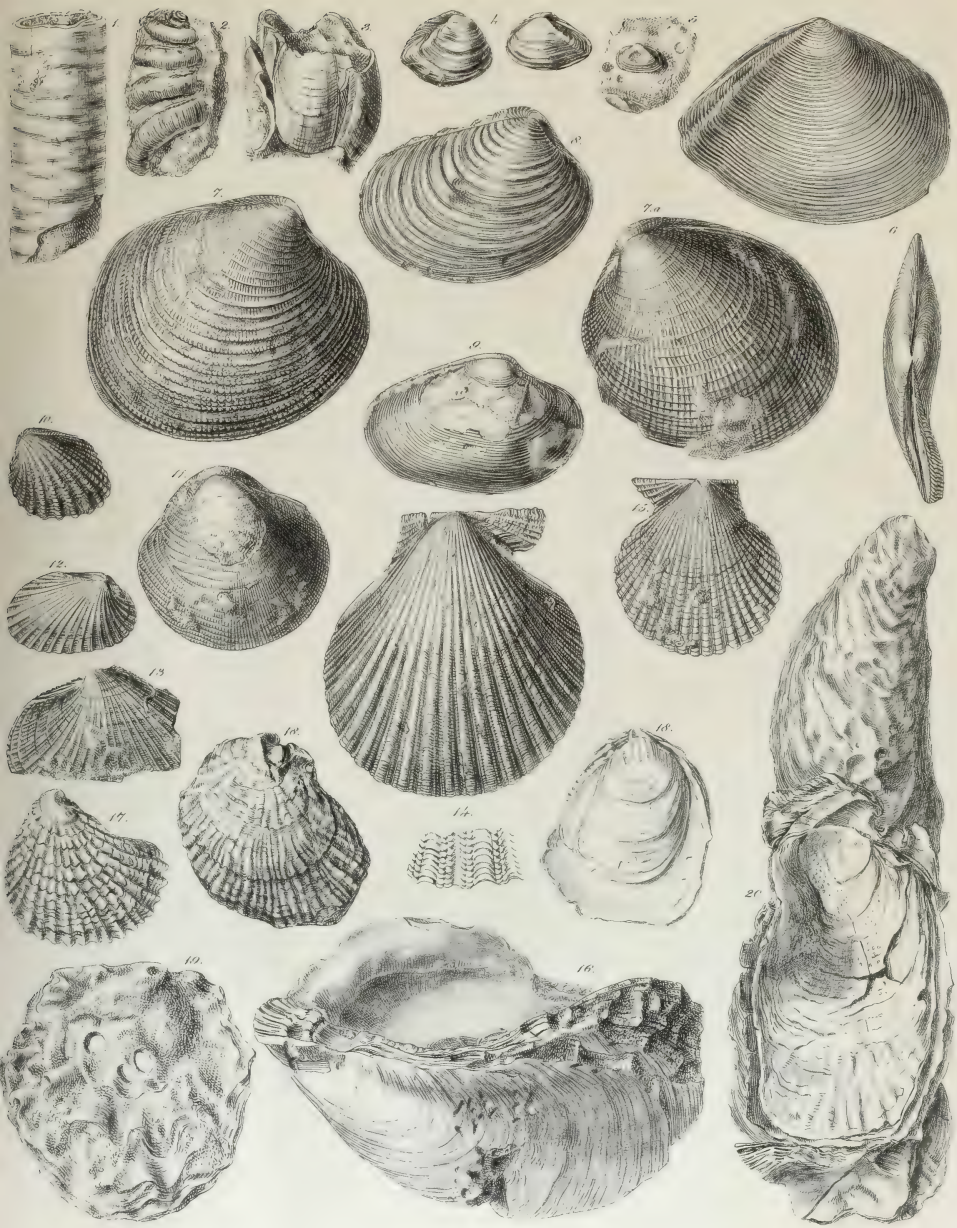
16.

TERTIARY.

TERTIARY FOSSILS.
CUTCH.



1.
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36.

UPPER FORMATIONS
of the
NEW RED SANDSTONE SYSTEM,
IN
GLOUCESTERSHIRE, WORCESTERSHIRE
AND WARWICKSHIRE.

to illustrate the Memoir

by Mr Murchison & Mr Strickland

P. 331

Fig 1 *p 333*

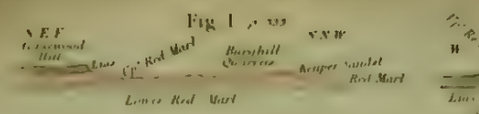


Fig 2 *p 333*

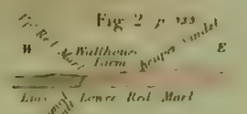


Fig 3 *p 333*

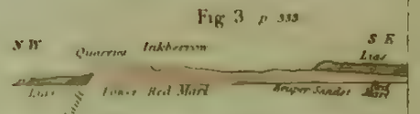


Fig 4 *pp 333 337 343 345*

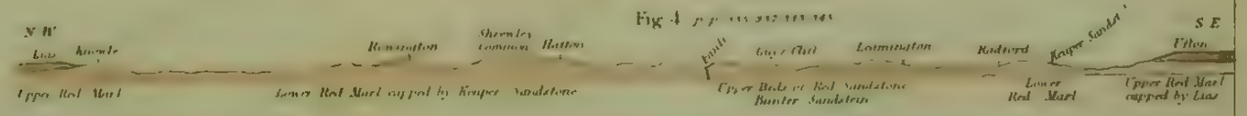
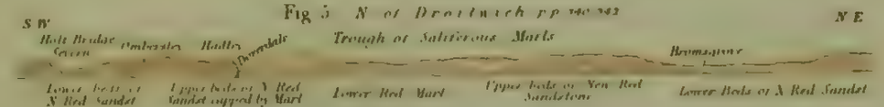
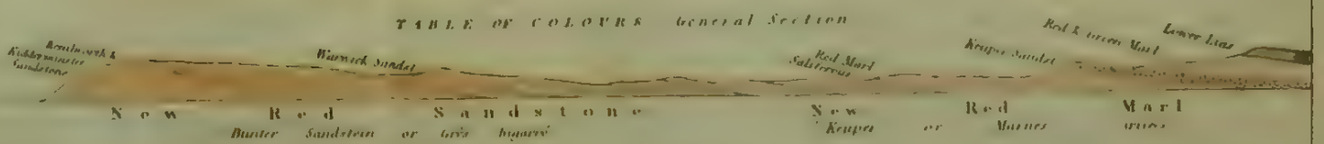


Fig 5 *N of Droitwich pp 340 343*





Scale of Miles for Map & Horizontal distance of Sections

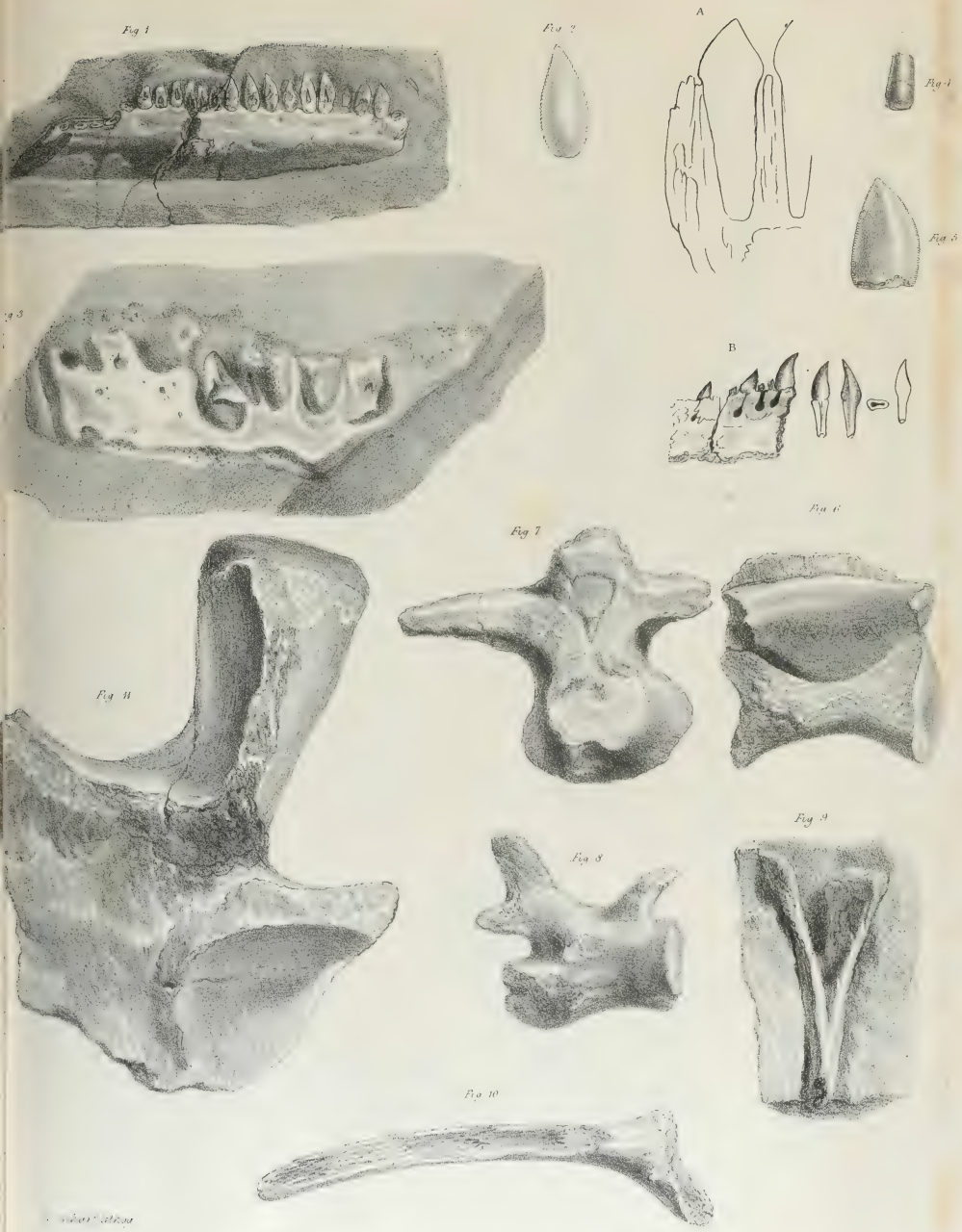
0 1 2 3 4 5 6 7 8 9 10 Miles

Fossils of the Keuper Sandstone p. 330

Fig 1 Slab of Sandstone with ripple marks and impressions of footsteps Fig 2 The footsteps Fig 3 Ichthyodorulite of Hybodus Keuperi
Fig 3a Fragment of the ribbed surface Fig 3b Portion of interior Fig 3c Tooth of an Hybodus Fig 4 Posidonomya minuta

Fossils of the Bunter Sandstone p. 340 et seq

Fig 5 Portion of the lower jaw of a Fish Fig 6 7 Teeth of Megalosaurus Fig 7a A Tooth from Leamington Fig 8 Teeth of a Saurian
Fig 9 A Tooth found at Leamington Fig 10 Vertebra of a Saurian Fig 11 11a Echinostachys oblongus p. 341



Saurian Remains from the Magnesian Conglomerate

SECTIONS on the COAST of SUFFOLK and ESSEX to accompany the Rev^d W B Clarke's, Memoir p 359

Fig 1 p 362 – Coast Section from Walton (Suffolk) to Bawdsey Haven, Mouth of the Deben, Horizontal Scale 8 Inches to a Mile, Vertical Scale to Horizontal 3 to 1.

Fig. 2. p. 362 – Coast Section from Bawdsey Haven to the ancient embouchure of the Alde N of Aldeburgh.

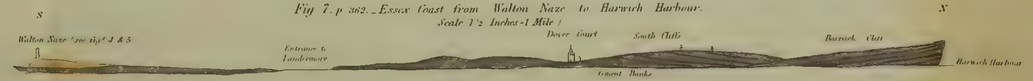
Fig 3. p 362 – Section from the Mouth of the Stour to Landguard Fort
Scale 4 Inches = 1 Mile

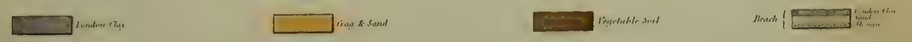
Fig 4 p 362 – Front View of the Naze Cliffs, Walton Essex

N° 5. p. 362 – Profile of Walton Naze & Ridge

Fig. 6 p 362 Crag & Gravel near Wallers Farm Stratford St Mary, Suffolk, at the 60th mile-stone from London

Fig 7. p 362. – Essex Coast from Walton Naze to Harwich Harbour.
Scale 1 2 Inches = 1 Mile.





Saurian Remains from the Magnesian Conglomerate p. 349

Fig 1 to 6 reduced to one half the Natural Size

7 to 13 Natural Size

MAP AND SECTIONS
of the
ENVIRONS of SMYRNA
to accompany
Mr H E Strickland's, Memoir
p 393
Hermus R.
MENIMEN
Mount Gordileon
Kizghioul
Sec 5
Village
Pelangie Fort
Sec 1
Bournabat
Menimen Scala
Delta of the Hermus
BAY OF SMYRNA
SMYRNA
Plain of Bournabat
Sandjak Castle
Hot Bath
Baltchikeui
Two Brothers
Mount Corvus
Boudjah
Cafinet
Plain of Sedikeui
Sedikeui
Cuckluja
Bournarbashi
Gavakludere
Mt Tartali
Hadjilar
Ishakli
Yorlikeui
Gafinet
Djakikeui
Vale of Nimphi
Nimphi
Nimphi Chay
Mount Tmolus
Tartali Chay
Phyrites R.
Truanda
Fortena
Plain of Tourbali
To Ephesus
To Menimen
MAGNESIA
Spring
Bonisha
Mount Sipylus
To Gassaba
To Magnesia
To Gassaba
To Tourba
Scale of Miles
1 2 3 4 5
No 1. General Section across the district of Smyrna. pp 397 398 399 400.
Near Megalos Paradisos
Mount Pagus
Caravan Bridge Smyrna
Plain of Bournabat
Bournabat
A
N E
No 2. Across the River Meles p 397 399
E
Tower of the Pomerium
Lower Road to Boudjah
Mount Pagus
Smyrna
Aqueduct over the Meles
Trachyte
Trachyte
Sandy beds with leaves and lacustrine shells
No 3 Enlargement of Section No 1 at A. p 400
Trachyte
Tumeur & Conglomerate
Conglom of Grey Limest Quartz & Schist
White & Yellow Marls with Lacustrine shells
Pumiceous Tuff
Grey Limest & Schist
No 4 West Side of Stream ½ Mile N of Bournabat p 400
S
N
Trachyte
White Marls with Cardiaceous Lacustrine shells
Brown Clay with Leaves & Shells
No 5 About 5 Miles N of Bournabat p 401
W
E
Trachyte and Conglomerate
Lake of Kizghioul
Pumiceous and Sandy tuff
Ravine
Trachyte
Trachyte Conglom
Mesozoic schist and Marble
Hippurite Limest & Greenish schists
Lacustrine Limest & Marls & numerous gravel
Trachytic Rocks
Lacustrine gravel with trachytic pebbles
Modern alluvium

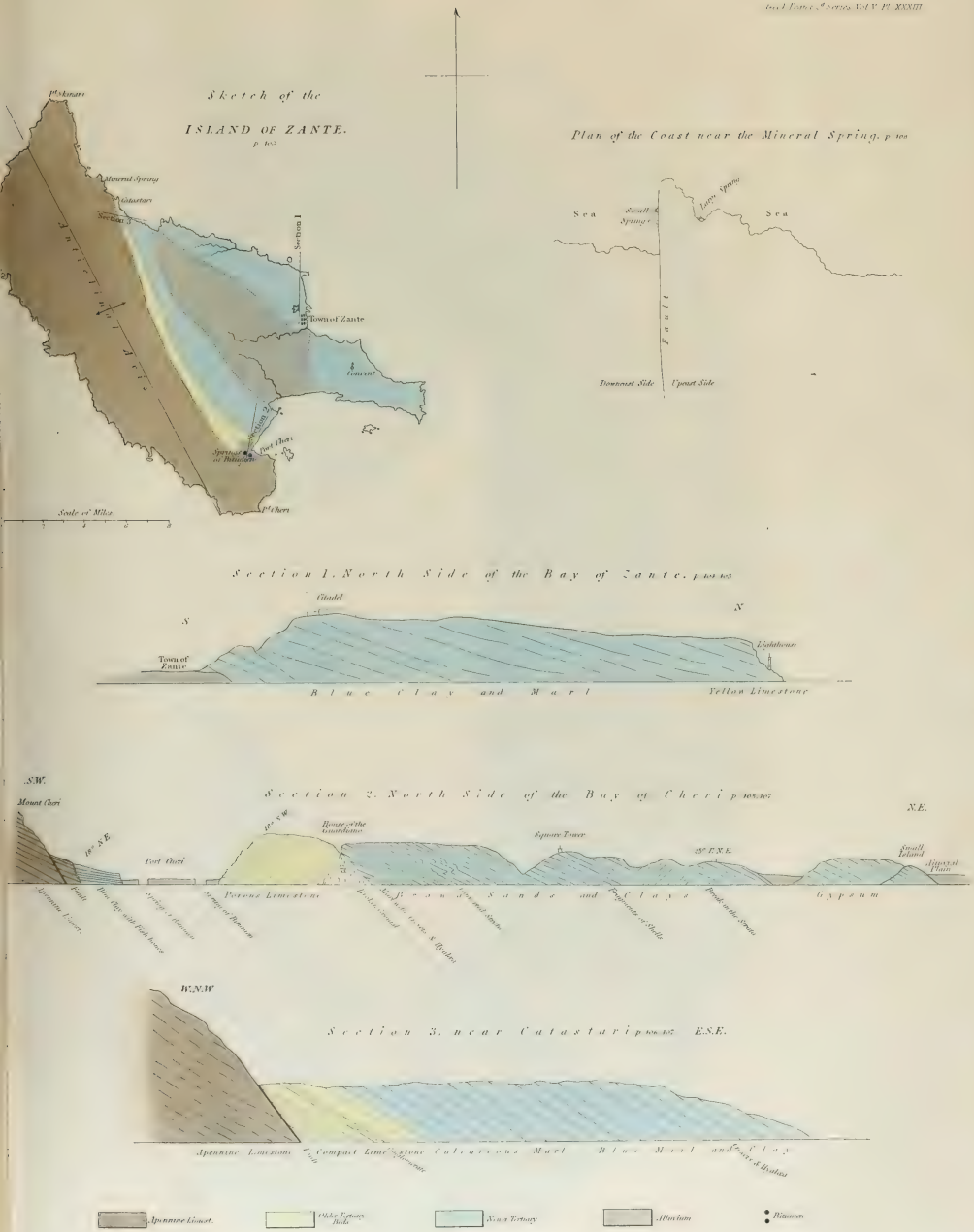
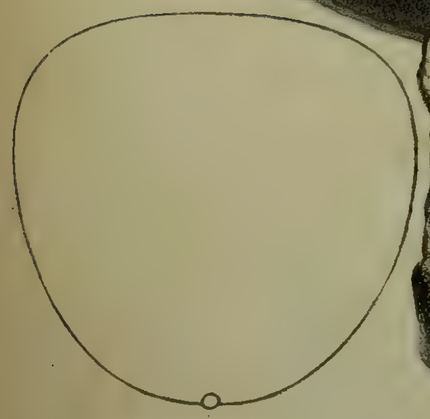

Sketch of the
ISLAND OF ZANTE.
p. 103
Pt. Skinari
Mineral Spring
Catastari
Section 3
Section 1
Town of Zante
Convent
Section 2
Port Cheri
Springs of Bitumen
Pt. Cheri
Scale of Miles.
Plan of the Coast near the Mineral Spring. p. 108
Sea
Small Springs
Large Spring
Sea
Fault
Downcast Side
Upcast Side
Section 1. North Side of the Bay of Zante. p. 103 105
Citadel
S
N
Town of Zante
Lighthouse
Blue Clay and Marl
Yellow Limestone
S.W.
Mount Cheri
Section 2. North Side of the Bay of Cheri p. 105 107
N.E.
Port Cheri
House of the Guardiano
Square Tower
Small Island
Alluvial Plain
Porous Limestone
Brown Sands and Clays
Gypsum
Apennine Limest.
Fault
Blue Clay with Fish bones
Springs of Bitumen
Springs of Bitumen
Brecks Ground
Brecks Ground
Fragments of Shells
Break in the Strata
W.N.W.
Section 3. near Catastari p. 106 107 E.S.E.
Apennine Limestone
Compact Limestone
Calcareous Marl
Blue Marl and Clay
Apennine Limest.
Older Tertiary Beds
Newer Tertiary
Alluvium
Bitumen

Fig. 1

Fig. 1a



Lithog. from nature by G. Scharf

Half the Nat.l Size

Crioceratites Bowerbanku.
p. 410

Fig. 2

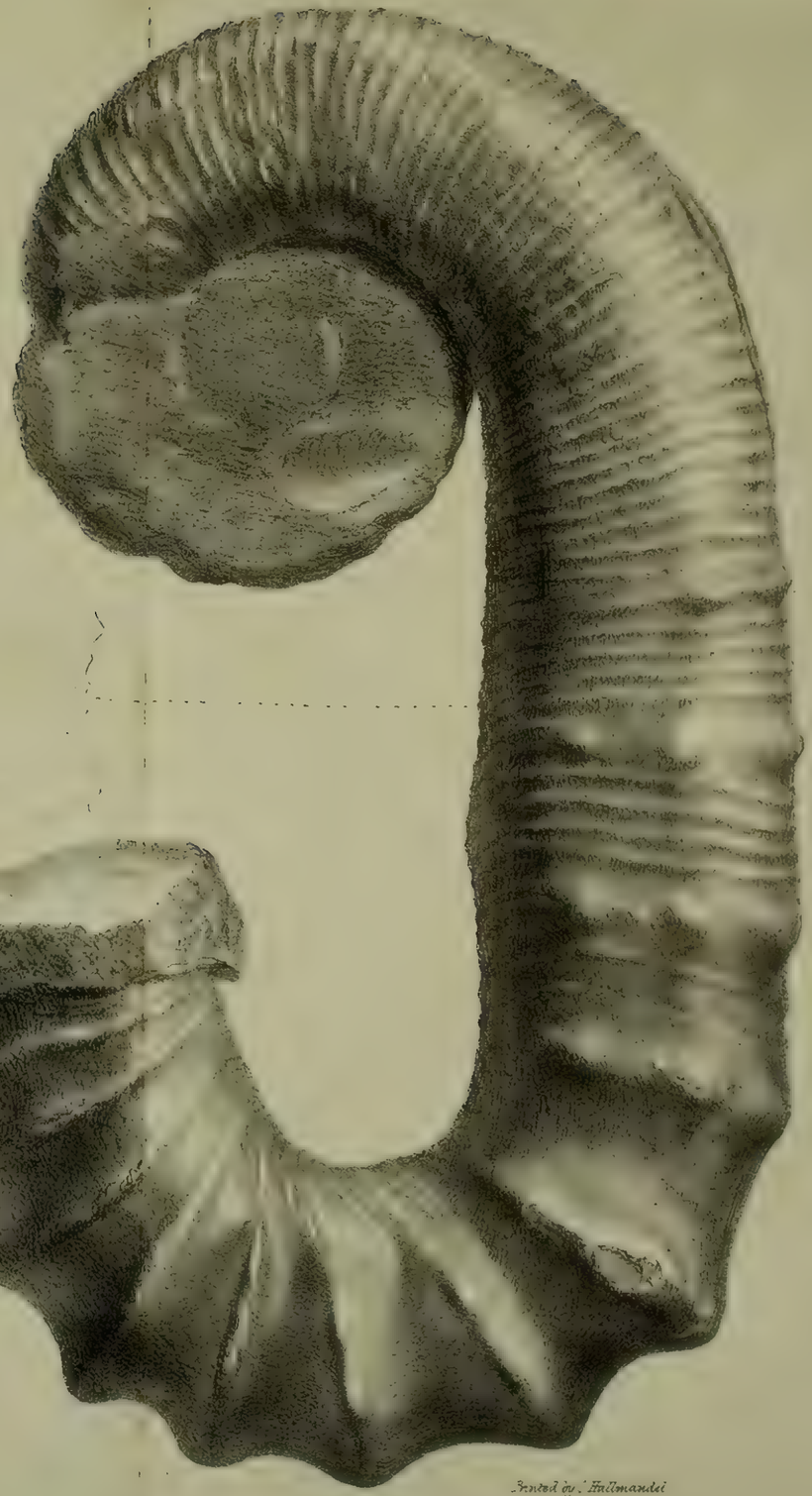


Fig. 2a

Printed by J. Hallmandel

Scaphites Gigas

Postscript to the Paper on the Geology of Zante, by H. E. Strickland, Esq.

Since the printing of the paper on the Geology of Zante, I have been favoured by Dr. Daubeny with the following analysis of the mineral spring described at p. 407:

Specific gravity, 1·020.
Solid contents in one pint, 174 grains.
Ferrocyanite of potash produced no effect, proving the absence of iron.
Barytic salts produced a cloud, proving the presence of sulphuric acid.
Nitrate of silver produced a dense cloud, proving much common salt.
Oxalate of ammonia produced a cloud, proving presence of lime.
Phosphoric test caused evident indications of magnesia.

From the above analysis it appears that the water of this spring differs but little from ordinary sea-water. Indeed, from the manner in which it rises in the sea, a large quantity of sea-water must unavoidably become mixed with it. At the same time, its inferior specific gravity, its milky colour, the flocculi of Glairine, and the strong smell of sulphuretted hydrogen, all serve to characterize it as a mineral spring analogous to those of volcanic regions.

H. E. Strickland.

TRANSACTIONS

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VOLUME V.

Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare ; atque non disputando adversarium, sed opere naturam vincere ; denique non belle et probabiliter opinari, sed certo et ostensive scire ; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant.

Novum Organum, Præfatio.

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1840.

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CORRIGENDA ET ADDENDA.

Page 302, *line* 7, *for* Turbinella *read* Turbinellus.
Page 348, *line* 4, *for* destructive *read* distinctive.
Page 353, *line* 6, *from bottom*, } *for* Plate XXIV. *read* Plate XXIX.
Page 354, *line* 7, }
Page 488, *line* 4, *from bottom*, *add* 8.
Page 493, *col.* 1, *line* 2 *from bottom*, the superior figure 5 refers to Pleuracanthus in bottom line.
——— *col.* 2, transpose two last lines.
——— *note* 5 *line* 2, *for* curve *read* groove.
Page 575, *line* 4, *from bottom*, *for* No. 1 *read* No. 2.
Page 667, *note* †, *for* 1837 *read* 1839.
Page 708, *note* †, *for* p. 710 *read* p. 712.
Page 709, *line* 21, *for* Pl. XL. *read* Pl. LX.
Page 728, *line* 26, *for* Cyrtia *read* Spirifera.

XXXIII.—*On the Geology of Coalbrook Dale.*

By JOSEPH PRESTWICH, Jun., F.G.S.

[Read February 5, 1834, April 13 and 27, 1836.]

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Introduction.

In the following pages two memoirs are embodied. One of them, read before the Society in February 1834, gave a short account of some of the principal faults and disturbances of the Coalbrook Dale coal-field; the other, read April 1836, described the several formations comprised in that district, as well as certain phænomena exhibited by the coal-measures, and not noticed in the former communication.

Before I proceed, it is necessary to observe, that prior to the researches of Mr. Murchison into the formations between the carboniferous rocks and the slates of Wales, the examination of the Coalbrook Dale district was attended with very considerable difficulties. A few of the rocks, which crop out

against the flanks of the Wrekin, had been ascertained to be counterparts of others; but their order of superposition and relative antiquity had not been determined.

Mr. Murchison's labours, however, have removed these difficulties, by showing, that the thin zones of gray and liver-coloured sandstones, shales, and limestones, which overlie the limestone at Wenlock, and underlie the coal-measures at Madeley, Broseley, &c., are referable to the Ludlow rocks, the first formation beneath the old red sandstone, and constituting, with the Wenlock limestone and shale, the upper Silurian group; and that the shelly sandstone at Morrell's Wood, as well as the quartzose grit, and dark-coloured flags at the base of the Wrekin, belong to the Caradoc sandstone, or lower Silurian rocks.

The deposits just noticed form, in this district, the terminating points of the formations, which having thinned out from their full developement in South Shropshire, Montgomeryshire, Radnorshire, &c., merely constitute, in the neighbourhood of the Wrekin, small and irregular masses, possessing but few of the characters, which distinguish them elsewhere.

These changes have tended to produce considerable intricacy in the geology of this interesting and beautiful district, where, within a few miles, we find a nearly complete epitome of the carboniferous and Silurian systems.

I beg leave to acknowledge most particularly Mr. Murchison's kindness, in affording me every assistance respecting the Silurian series. I am also indebted to that gentleman for the use of a valuable, manuscript Ordnance Map, on which the heights of the principal hills were marked. This document has been of very great service to me in constructing the sections.

Mr. Arthur Aikin, in his memoir on the Geology of the South-Western part of Shropshire *, gives a general sketch of this portion of the country. To the accuracy and value of the mineralogical details given in that memoir, I can bear ample testimony; but the extent to which the coal-field was worked at the period of his visit, about twenty years since, was much less than it is now; and he was consequently prevented from entering into those details, for which his ability and perseverance so well qualified him.

Dr. Townson † has given many interesting particulars of the mineralogy of Shropshire; and some notice has likewise been taken of it by the Rev. Mr. Plimley ‡.

During the whole of my researches, I experienced from all parties much attention and courtesy. To Mr. Anstice, of Madeley, I am particularly indebted for a constant readiness and kindness in furthering my inquiries. By

* Geological Transactions, First Series, Vol. i. p. 191 *et seq.* † Townson's Tracts.

‡ Plimley's Agricultural Survey of Shropshire.

being permitted at all times to examine his fine collection of fossils from the coal-measures, I have been enabled to add considerably to my catalogue of organic remains; and it was in certain nodules in his cabinet, that I discovered the two impressions, which Dr. Buckland has since shown to belong to coleopterous insects*. Mr. Anstice's long practical acquaintance with the Madeley coal-field, enabled him also to favour me with many interesting particulars respecting the Madeley and Limestone faults; and I am indebted to him for the excellent sections of the Madeley Pits.

I must likewise acknowledge the assistance, which I received during the progress of my inquiries, from the Messrs. Pritchard and Mr. J. Onions of Broseley, Mr. Thomson of Lightmore, Messrs. Darby of the Dale, Mr. Hombersley of Prior's Lee, and Mr. Jones of New Hadley. The ground-bailiffs throughout the whole district, always evinced much civility and readiness in accompanying me over their works, and giving me every information in their power.

I cannot conclude without expressing my grateful obligations to Mr. Lonsdale, to whose kind suggestions and constant assistance, I feel very greatly indebted.

Extent and Physical Features.

The district to be described, is included within an acute-angled triangle, the termination of the zone of Silurian and carboniferous rocks, which ranges through Wales, Herefordshire, &c. This apex of the triangle, near Newport, points about N.N.E.; and its two longer sides, ranging respectively about S.W. and S., are flanked by the new red sandstone. The coal-measures extend from the acute apex of the triangle at Church Aston, near Newport, to Steeraway, a distance of seven miles; and they attain their greatest breadth, $3\frac{1}{2}$ miles, in the parallel of the latter locality. At this point, the Silurian rocks gradually swell out, and reduce, as we proceed southward, the coal-measures to an irregular and decreasing band, which at Tasley, near Bridgenorth, is only three-quarters of a mile in breadth. The total length of the coal-field from Church Aston to Tasley is 15 miles; its area is about 32 square miles; and that of the whole district to be described is about 100 square miles. (See Map, Pl. XXXV.)

The surface, occupied by the Silurian and carboniferous rocks within the triangle, is considerably higher than the surrounding country, composed of the new red system. To the east, the surface of this system is undulated

* See Dr. Buckland's Bridgewater Treatises, vol. i., p. 409.

and diversified, and gradually decreases in altitude as it recedes from the older rocks; but to the north and north-west, the higher platform of the coal-measures descends rapidly into the lowlands of the new red system.

At Watling Street, near Wellington, commence the lofty igneous axes of the Ercal and Wrekin, Steeraway and Maddox, which constitute the boundary in this portion of the area, and separate the coal-measures from the new red sandstone.

On the south-west no physical feature bounds the district; but the reader may supply this deficiency, by drawing a line from the end of the Wrekin to Wenlock Edge, and thence to Bridgenorth.

Having thus defined, generally, the limits of the districts, I will describe briefly, the principal physical features within them.

The Severn divides the area into two unequal portions. Where it enters the district from the west, it traverses a valley in the Caradoc sandstone, one of the Lower Silurian rocks; it then passes through a narrow and beautiful valley of Wenlock shale, flanked on the north by the hills of Little Wenlock and Sunnyside, and on the south by the finely wooded and precipitous escarpments of Wenlock Edge, Gleedon Hill, Tickwood Hill, and Benthall Edge. Near Coalbrook Dale the valley rapidly contracts, and the Severn enters a deep and narrow gorge in the Wenlock limestone, separating Benthall Edge from Lincoln Hill. This gorge passes immediately into the coal-measures, and intersects them for about two miles, to Coalport. A little beyond that point, the river turns southward, and is bounded on the left by an escarpment of new red sandstone, and on the right by hills of coal-measures, as far as the Wren's Nest, beyond which it flows through precipitous ridges, wholly composed of the new red system. Between Coalport and Bridgenorth the hills are beautifully wooded, and intersected by numerous glens. To the south of the Severn, the country is so traversed by deep valleys and ravines, that, with the exception of Wenlock Edge, no connected ridge of hills can be traced. The leading features, however, are, the fine and bold escarpments of Wenlock and Benthall Edges, and Sherlot Hill, which, rising to the height of 731 feet, constitutes the greatest elevation of the coal-measures, in this portion of the field. To the north of the Severn, the surface is less generally broken, the part occupied by the coal-measures, presenting an elevated and undulating outline, which averages about 400 feet above the level of the sea, or 300 feet above that of the Severn at the Iron Bridge. Their greatest elevation is 746 feet. The most prominent features in this portion of the field are the Wrekin, which rises to the height of 1320 feet above the level of the sea, and

the parallel easterly ranges of igneous rocks and mountain limestone, and of Lilleshall Hill, at the northern apex of the field. Some of the other irregularities of outline will be noticed in describing the faults.

The coal-field was once thickly wooded; and in the names of many localities, as Broseley Wood, Cow Wood, Donnington Wood, &c., are preserved the remembrance of that state of the surface, though they now present a far different scene. The trees are replaced by engines and furnaces, and the green sod by pit-mounds, destitute of the slightest verdure; still, with the exception of a portion of the coal-field, the country around Coalbrook Dale is extremely beautiful and picturesque, and I know few parts of the kingdom which, within so limited an area, present a greater diversity of fine scenery.

The highly-cultivated lowlands to the north—the noble valley of Shrewsbury, bounded by the Welsh mountains, and irrigated by the winding Severn and the numerous bold escarpments and woody dingles, which skirt and branch off from the banks of that river, present a continual change of romantic and picturesque scenery.

The boundary of the coal-measures reposes successively on several members of the carboniferous and Silurian systems. At Lilleshall, it rests upon carboniferous limestone; between that point and Steeraway Hill, it abuts against the new red sandstone; and from Steeraway to Little Wenlock, it overlies the highly-inclined outcrop of the carboniferous limestone. Turning thence eastward by Harris Coppice to the Dale, it reposes upon the Wenlock shale, and at Lincoln Hill upon the Wenlock limestone. Crossing the Severn, the coal-measures are displayed resting on the Wenlock limestone of Benthall Edge, to the south-east of which they overlie the Ludlow rocks as far as Linley hill, where they are in contact with the old red sandstone, but a little to the eastward of Linley Hall they again repose, for a short distance, on Ludlow rocks. Throughout the remainder of the district, to the south on to Tasley, they overlie the old red sandstone. At Barrow and Sherlot Hill are two outliers of coal-measures, the former resting partly on Ludlow rocks, and partly on old red sandstone, and the latter wholly on the old red. Along the entire eastern boundary of the field, the carboniferous strata abut against or dip under the new red system.

Thus the coal-measures repose upon carboniferous limestone, old red sandstone, the several divisions of the Ludlow rocks, the Wenlock limestone, and shale, and occasionally on trap. (See Map and Sections, Plates XXXV., XXXVI.)

I will now proceed to describe each formation, commencing with the oldest sedimentary deposits.

Lower Silurian Rocks.

Pl. XXXV. and XXXVI., fig. 5, 6, 7, 14, and 15.

Caradoc Sandstone.

This division of the great system, worked out by Mr. Murchison in the border counties of England and Wales, is in the Coalbrook Dale district, but imperfectly developed. Its lower member is a coarsely-grained quartzose grit, which forms a belt around the trap of the Wrekin, Ercal, and Lilleshall hills. The strata incline at a high angle against their flanks, but the dip rapidly decreases as we recede from them. Portions of the rock disintegrate rapidly, owing to its broken state and loose texture; but the sandstone or grit is frequently very pure, and occasionally so free from iron, that it has been quarried for the use of the china manufactory at Coalport. Mr. Murchison attributes its clear white colour and friable texture, to the action of the igneous rocks which protrude through it. Between the Wrekin and the Ercal it presents the appearance of a gravel, composed of small angular fragments of hard grit, mixed with a few larger masses, and coloured, as well as slightly cemented, by the peroxide of iron. As far as my observation extended, this rock does not contain any organic remains. At the south-eastern extremity of the Wrekin, near the road from Leighton to Wenlock, and in a quarry by the road side, at the eastern entrance of the glen, which divides the Wrekin and the Ercal hills, there reposes upon this quartzose grit, a dark greenish micaceous flag, the mica being so abundant at a pit, on the western side of the lower Wrekin, that the rock disintegrates into a fine powder. It is, however, generally small-grained and hard, breaking into rhomboidal masses. At the second quarry between the Wrekin and Ercal hills, the flagstone is in immediate contact with the basalt, which has tilted it into a nearly vertical position; but the general dip of this rock is conformable to that of the underlying grits. I could discover in it no trace of fossils. The strata in the immediate vicinity of the Wrekin and Ercal are so broken and shattered by the protrusion of the igneous rocks, that it is extremely difficult to trace their continuity; and the schist is not often exposed, although it may probably form a narrow belt, from ten to twenty yards broad, parallel to the underlying grits.

As we recede from the Wrekin, coarse- and fine-grained ochreous and greenish sandstones, alternating with beds of light gray clay, dark gray and liver-coloured shales, and impure gray limestones, make their appearance. These beds have been recognized by Mr. Murchison, as belonging to the Caradoc Sandstone.

They range on the eastern side of the Wrekin, and parallel to its major

axis, from near Watling Street to Leighton and Shineton, and thence southward. The dip varies considerably, either conforming to the flanks of the numerous masses of trap, or to that of the subjacent grits and schistose flags.

This rock is well characterized by its organic remains, which are numerous in the bands of limestone; the most common being the *Pentamerus lævis*, *Orthis alternata* and *Tentaculites annulatus*, with several Crinoidea and corals. Mr. Murchison mentions many new species of Pentamerus, Nucula, Orthis, and Trilobites, as characteristic of the deposit in other districts*.

UPPER SILURIAN ROCKS.

The Wenlock Shale. (Pl. XXXV. and XXXVI., figs. 8 to 11, 13, 14 and 15.)

In the neighbourhood of Leighton Hurst and Morel's Wood the Caradoc sandstone disappears under a calcareous shale, belonging to this formation.

It is well and extensively developed, and rises from below the Wenlock limestone, which constitutes the upper part of the escarpment of Wenlock Edge, Benthall Edge, and Lincoln Hill. The shale, in each instance, forms the base of the range, and extends across the valley of the Severn to the escarpment of the coal measures, below which it disappears. Good sections of it are exposed along the banks of most of the brooks by which it is intersected, and on the sides of the Severn, at Buildwas. It is uniformly a thin, laminated, calcareo-argillaceous shale, sometimes finely micaceous, and it occasionally contains nodules, and a few thin, subordinate beds of impure limestone. Its colour varies from light greenish gray to light liver. It is tenacious and adhesive when wet; but when dry, it splits into imperfectly rhomboidal masses, having an earthy fracture. It has been proved to extend as far north as Lightmoor, where, at a depth of eighty yards, and underlying the coal-measures, Mr. Thompson met with a calcareous shale, which, by its fossils, I recognised as the Wenlock shale. Its organic remains are numerous and beautifully preserved. Among the most characteristic in the neighbourhood of Coalbrook Dale are, *Asaphus caudatus*, common in groups in the upper part of this formation, *Orthis testudinaria*, (Sow.), *Orthoceras annulatum*, (Sow.), and *Terebratulæ*, with a few crinoidea and corals.

The Wenlock Limestone. (Pl. XXXV. and XXXVI., figs. 9 to 14.)

The Wenlock shale passes gradually upwards into the Wenlock limestone, which presents a steep escarpment over the vale formed of the shale. The limestone ranges through the district in a narrow belt from Lincoln Hill to Much Wenlock, and thence in a south-westerly direction into Wales. South-

* Silurian System, p. 704, *et seq.*

ward of Much Wenlock, the limestone escarpment has a very regular strike south-west and north-east, and the strata at the outcrop, along its summit, dip about 25° south-east, the inclination decreasing in following the direction of the dip. About two miles north of Much Wenlock, the escarpment is broken through by numerous transverse glens, marking the range of large faults; and the strata dip in all directions. The synclinal line along Farly Glen, and the dome-shaped structure of Tickwood, resulted apparently from these fractures and disturbances*.

The belt of limestone reassumes its usual regularity at Benthall Edge, with a strike E.N.E. and a dip from 20° to 25° S.S.E. At the large quarry about midway along this ridge, the basseting edges of the limestone dip at an angle of 26° S.S.E., but the dip rapidly decreases as the strata recede from their outcrop, being only 16° at the distance of 70 feet from that point; and still further in the same direction, the strata are comparatively horizontal, and are overlaid unconformably by the coal-measures.

This arrangement prevails the whole length of the escarpment, but at Lincoln Hill, the strata, instead of forming, as at Benthall Edge, a short and rapid curve, are very singularly contorted. These undulations are well exposed in the limestone caverns, in the eastern flanks of the hill, and extend along the plane of the rock to a depth of 100 yards from its basset. The strata dip at an angle of about 55° for the first few yards; they then begin to curve gradually; but about 80 yards from the outcrop the undulations present a series of very slightly convex planes, 20 yards in breadth, and separated by rapid, step-formed descents, from 4 to 6 yards in the fall, and the apex of the curves exhibiting no fracture in the limestone.

The escarpment of this rock finally disappears below the coal-measures, near Castle Green, and though it does not crop out, it has been proved to continue as an underground ridge in the same direction, at several coal-pits lying in that plane in the parish of Madeley. (See Map and Sections.)

The upper beds of the Wenlock limestone are thin and argillaceous, and of a light gray or blue colour. In proportion as the series descend, so the strata are thicker and more compact. The central beds are extensively quarried, both for agricultural purposes and the iron furnaces. At Wenlock, Gleedon Hill, and Tickwood they are extremely pure, of a very light gray colour, but sometimes tinged or rather speckled of a light flesh colour, owing to the imbedded Encrinites. The structure is concretionary and the fracture

* Mr. Philips notices similar effects from like causes in the scar limestone of Yorkshire, (see Phil. Geol. of Yorkshire, vol. ii. p. 114.) Mr. Murchison also explains the phænomena of Woolhope, and the Wren's Nest by the doctrine of valleys of elevation.—Silurian System, p. 428, *et seq.*, and p. 483, *et seq.*

conchoidal. The masses which constitute the strata frequently form large, irregularly-rounded blocks, highly crystalline and pure. They are termed "ballstones," and form an excellent flux for the ironstone. The lower strata of this limestone are well exposed in the numerous quarries along Benthall Edge and at Lincoln Hill. Their colour is dark bluish gray, and their texture is more earthy than the central strata, which are also much thicker bedded. Strongly-defined lines of cleavage or joints traverse this limestone; and are well exhibited in the quarries at Benthall Edge, one set ranging nearly at right angles to the strike of the rock, and the other almost parallel to it. The direction of the first is nearly true north and south; that of the second about 12° S. of west and 12° N. of east. At the "Vineyards," (half a mile further westward,) where the strike is a few degrees more south, the direction of the joints is still the same. At Gleedon Hill, they hold a similar course, whilst the dip is 12° north; but, at Bradley, intermediate between these two places, the dip is about 8° W.S.W., and the cleavage is apparently nearly N.W. and S.E. This district is, however, so much disturbed, that it is difficult to arrive at any certain conclusion.

Mineralogical Contents.—In the Wenlock limestone, there are no ores in sufficient quantity to repay the working. Crystallized carbonate of lime occurs in the seams and partings of the strata, frequently forming beautiful rhombic, tetrahedral, and hexahedral crystals. Flesh-coloured sulphate of barytes, splitting into rhombic crystals, is common in the fissures of the limestone at Benthall Edge. Small crystals of sulphate of copper are occasionally disseminated upon the crystals of carbonate of lime; and the sulphurets of iron, copper, and lead are met with in small lumps and in thin filaments in the lower part of the limestone. The peroxide of manganese also occasionally fills up small cavities and fissures in the rock. In the central beds are sometimes found geodes of a very pure limestone, the cavities of which are lined with beautiful crystals of calcareous spar.

Organic Remains of the Wenlock Limestone.

Fossils abound in this formation, and are in general extremely well preserved, especially the corals which are found in the central limestone at Gleedon Hill. In that portion of the formation are beds, sometimes more than 20 feet thick, composed almost entirely of remains of Crinoidea, of white and pink colours, the limestone thereby acquiring a curious, speckled appearance. The substance of the corals is frequently replaced also by a pure, semi-transparent pinkish carbonate of lime, which has beautifully preserved the most delicate internal structure. In the lower beds, Crinoidea are much less numerous, occurring only in detached fragments between the strata; but they contain great abundance of Favosites, and several species of Eumophalus, Leptæna, and Pleurotomaria. In the uppermost beds organic remains are less abundant than in the middle or lowest, and are almost entirely confined to Testacea.

The following is the list of the fossils procured by me in this district :

Calymene Blumenbachii, — very scarce, I found but one specimen at Lincoln Hill.
Asaphus caudatus, rare.
Euomphalus rugosus, Sowerby's Mineral Conchology, very common at Benthall Edge.
———— *funatus*, Sow., less common at Benthall Edge and Lincoln Hill.
———— *discors*, Sow., less common at Benthall Edge.
Pleurotomaria, rare.
Cornulites serpularius, Schlotheim Petrefactenkunde, rare.
Orthoceras annulatum, Sow., and *O. giganteum?* Sow., rare.
Atrypa (*Terebratula*) *affinis*, Sow., numerous at Benthall Edge and Lincoln Hill.
Leptæna (*Producta*) *depressa*, Sow., and *L.* (*Producta*) *euglypha*, Sow., common at ditto.
Orthis rustica, Sow., common at ditto.
Lingula, large species, very rare.
Spirifer radiatus, Sow., common at Benthall Edge.
Stromatopora concentrica, Goldfuss Petrificata, common at Benthall Edge.
Catenipora escharoides, Lamarck Anim. sans Vertèbres, ditto.
Millepora repens, Hisinger Lethæa Suecica, ditto.
Favosites Gothlandica, Lamk., and *F. alveolaris*, Goldfuss, ditto.
Porites pyriformis, Ehrenberg, Berlin Trans., 1832, ditto.
Cyathophyllum hexagonum, Goldf., common.
Cyathocrinites rugosus, Miller's Crinoidea, very abundant at Gleedon Hill.

In this and other lists of Silurian fossils, only those species are included which were found by myself, and of those only a portion, a great number not being yet described. I must refer to Mr. Murchison's work on the Silurian System for complete catalogues; see also the list p. 490.

Ludlow Rocks. (Pl. XXXV. and XXXVI., figs. 1 and 9 to 14.)

Mr. Murchison, after determining the geological position of this zone of rocks, examined it as far as Much Wenlock, and along the New Cut at The Dean near Broseley; I have traced its prolongation from Much Wenlock to near Apley, at various points, where they have been protruded from beneath the coal-measures by the action, which produced the great faults that traverse this district.

The lowest division consists of greenish gray, slightly micaceous, soft sandstone and flags, with calcareous shales and impure limestone, inclosing a few casts of a *Pentamerus* and an *Atrypa*. It appears in the valley of Much Wenlock, whence it ranges to Wyke, but it disappears at Posenal, underneath the coal-measures; below which, however, it trends through Broseley to Madeley, and parallel to the strike of the Wenlock limestone. The gorge of the Severn exposes a small portion of this rock at the Iron Bridge. It has been met with in the meadow-pits in Madeley parish and at the Tuckiss, Balls, and other pits in Broseley parish. It also crops out from below the coal-measures in the lower part of Darley Brook, and it ranges thence to

within a quarter of a mile of the new red sandstone, and passes gradually into the next division.

The middle division or the Aymestry limestone, is formed of very thin and rough beds of light gray and bluish, lumpy limestone, with a few seams of clay; and is characterized by a great abundance of *Terebratula Wilsoni*, many of which are detached between the layers of limestone; and by a few corals. It is well exposed along the New Cut near Broseley, between Dean and The Dean, where it is brought up by a S.W. and N.E. slightly-developed anticlinal line, the prolongation of which may be seen at several places, along the slope of the hill, and particularly at Willey Church. I have traced this deposit from the New Cut to Willey, also in the bed of Darley Brook; and the junction strata between it and the upper divisions, again appear on the side of the lane leading from Barrow to Posenal; it may be traced thence by Ash Coppice, dipping 10° E.S.E. along the summit of the hills, to the east of Much Wenlock, where it forms a range parallel to the limestone escarpment of Wenlock Edge. From The Dean, it passes below the coal-measures to nearly opposite Swinney Mill, on the side of the Severn, and close adjoining the out-crop of the new red sandstone, where it has been found at a depth of 40 yards, underlying the lower coal-measures. At Aymestry, the limestone passes upwards into thin beds of a yellow, deeply ferruginous, very soft, and fissile sandstone, full of the *Orthis lunata*, *Leptæna* (*Producta*) *lata*, *Cypricardia undata*, and *Terebratula lacunosa*.

The upper division. The beds above mentioned rapidly give way to the sandstones of this division; the lower beds of which are light-coloured, thin-bedded, frequently very micaceous and fissile; and sometimes very much resemble the lower sandstones of the coal-measures*. The upper beds are occasionally highly micaceous and of a deeper colour.

The junction of this formation and the old red sandstone is well exposed near Callaughton, where the former is exhibited in several quarries. Thence it ranges to Wenlock Walton and Barrow Hill, dipping at an angle of about 8° under the old red sandstone. It is again brought to day on the summit of Breakneck and Willey hills, by the Swinney fault throwing it into juxtaposition with the coal-measures, which at the Dean's Corner, appear at the base of the last-mentioned hill. (See Pl. XXXVI., Section 13.) It then ranges under the thin capping of coal-measures at Linley Green Hill, and reappears at Linley Hall. In the brook below the Hall, good sections of it are exposed, overlaid by the old red sandstone, the beds being nearly horizontal or dipping

* An experienced collier informed me, that the fissile sandstone capping Willey Hill, and exhibited on the side of the lane leading from the Dean's Corner to Willey, was that which overlaid the best coal, and it was only after a long search, that the discovery of the Lingula proved the sandstone to belong to the upper Ludlow series.

very slightly S.S.W. From that locality, it extends almost to the Frog Mill near Coalmoor. This division is marked by a great paucity of organic remains; a Lingula and an Avicula being, though of rare occurrence, the characteristic fossils.

The formation is traversed by two sets of joints, the one ranging from N. 12° E. and S. 12° W. and the other W.S.W. and E.N.E. nearly.

The limited development of the Ludlow rocks in the district under examination, precludes an extensive list of the organic remains; and although the different divisions are well marked throughout, by the presence of several characteristic fossils, yet a great number of those, which Mr. Murchison describes as abounding further to the south, are here wanting.

THE OLD RED SANDSTONE.

(Pl. XXXV. and XXXVI., figs. 1, 12, 13, 14, and 16.)

This formation skirts the southern parts of the coal-field, reposing on the Ludlow rocks, and occasionally underlying the coal-measures. Along the edges of the former, to the S.E. of Much Wenlock, it consists of a very dark red clay, alternating with rather hard, dark red, speckled, or gray micaceous and fissile sandstones, and with thin beds of a gray, micaceous marl. In the red sandstone (dipping 12° S.E.) at Wenlock Walton, I found casts of the *Lingula cornea*, a characteristic fossil of the tilestone, or lowest division of the old red sandstone. In the lane to the southward of, and just below Barrow, the same beds are nearly horizontal, but I found no fossils. The old red sandstone here occupies a low tract, about one-third of a mile broad, insulating the outlier of coal measures on Shalot Hill. It then ranges around the base of Willey Hill and Linley Hill to Holly Bush, where a narrow tongue of it stretches eastward into the coal-measures. From the last locality, it may be traced, underlying the coal measures which cap the hills from Nordley, to Tasley. Dark red clays and marls predominate throughout the district, but they contain subordinate beds of coarse, highly micaceous, gray and red sandstones. The strata to the south and west are so covered with drift, that they can rarely be seen. It thus appears, that the old red sandstone reaches no further north than Barrow and Willey; and that at this extreme point, the lower division or the tilestones of Mr. Murchison, is moderately developed only in the western side, and that the spotted argillaceous marls and deep red clays, with their subordinate beds of sandstone, occupy the greater portion of the district forming the base of Shirlot Hill.

CARBONIFEROUS LIMESTONE.

(Pl. XXXV. and XXXVI., figs. 1 to 7, 13, and 14.)

In the south of the field, the coal-measures have been shown to repose upon

old red sandstone or Silurian rocks; but as we proceed north, the carboniferous limestone is gradually developed. Between Harris's Coppice and Little Wenlock, a very thin bed of limestone crops out from below the coal-measures, and abuts, to the north, against the trap of Little Wenlock. The limestone* again appears, in increased importance, to the north-west of Little Wenlock, constituting a singularly displaced band in the midst of the coal-measures, and extending northward about one mile, in which direction it passes, with a slight dip, conformably under the coal strata, whilst to the east and west it abuts against them. (Map, Pl. XXXV.) The true outcrop of the limestone ranges from the south-west of the trap of Little Wenlock by the Oldfield works, reposing upon the Caradoc sandstone and trap†, and thence trends N.N.E. to the Hatch and Steeraways, cropping out from under the coal-measure, and rising against the ridge of trap, at an angle of 40° at the Hatch, and of 25° at Steeraways. At the latter place its thickness is considerably increased, as is proved by the following section:

		Yds.	Ft.	In.	
1. White clod	Shale	3	0	0	Coal Measures 13 yds.
2. A hard gritty rock.	Pebbly sandstone	10	0	0	
3. Urchins	Clay and impure limestone	0	2	0	
4. Blacks	Dark bituminous shale	1	0	9	
5. Clod	Shale	1	0	0	
6. Fiery grit	Hard coarse sandstone	0	1	0	
7. Welsh Jack	Very hard compact fine gray sandstone	1	2	0	
8. Gallys	Shaly limestone	0	2	0	
9. Thick Measure	Dark gray argillaceous limestone	0	2	3	
10. Binds	Dark argillaceous fissile sandstone	1	1	0	
11. Ragged measure	Lighter coloured limestone	0	1	6	Carboniferous Limestone.
12. Clod and binds	Shaly sandstone	1	0	0	
13. Brown measure	Limestone	0	0	9	Average specific gravity of the limestone 2·67.
14. Binds	Fissile sandstone	0	2	9	
15. Double measure	Limestone	0	1	6	
16. Binds	Same as (14)	0	2	9	
17. Rough measure	Limestone	1	0	0	
18. Tough measure	Ditto, harder	0	0	6	
19. Flags	Hard sandstone	0	0	6	
20. Beadstone	Very impure clayey limestone	1	1	6	
21. Blacks	Bituminous shale	0	1	6	
22. Hard white rock	Hard sandstone, a few feet below which the basaltic rocks appear	1	1	0	
				16	1 3

* The fossils in this rock agree with those of the adjacent limestone of Steeraways, which Mr. Murchison has shown, by its organic remains, to belong to the carboniferous series.

† I am rather inclined to think that a deposit of trap of variable thickness underlies the carboniferous limestone from its first appearance near Little Wenlock to Steeraways.

In the road leading from the Hatch to the Wrekin, and in some other places, the superposition of this limestone on beds of trap, with their rise against the igneous axis of the Steeraways, is well exhibited. From Steeraways to Lilleshall the limestone is not exposed; but at the latter place, it forms a narrow band about $1\frac{1}{4}$ mile in length, overlying the trap and Silurian rocks, and rising from beneath the coal-measures. It abuts against new red sandstone on the west. The dip varies from N.E. to E. and is at different angles.

The north end of this wedge of limestone exhibits an apparently anticlinal line in the prolongation of the major axis of Lilleshall Hill, whence it might be supposed, that the limestone wraps all round that hill, but there is nothing further to support this hypothesis. The anticlinal dip takes place within a few yards of the Lilleshall fault, ranging parallel to it, and might therefore have been produced by the lateral pressure of the new red sandstone. The limestone at its outcrop near Lilleshall, is capped by a few yards of fissile sandstone, belonging to the coal-measures, which from the northward dip of the strata, rapidly acquire a greater importance, though not sufficiently to bring in the productive measures. This zone of limestone gradually decreases in width by the convergence of the Lilleshall and great east faults, and near Church Ashton it disappears in consequence of these faults meeting*. (See Map and Sections.)

Between Lilleshall and the pool at the bottom of the Hadley inclined plane, no sinkings have been made, which could point out exactly its course below the coal-measures: in digging "the pool," however, the limestone is said to have been met with, striking parallel to the fault. It was reached also in a pit sunk by Mr. Hombersley about half a mile south of Watling Street, at a depth of 80 yards, and in a nearly horizontal position. At Steeraways the limestone has been traced only a few yards below the coal measures; but its range under them has been lately confirmed, by its having been noticed rising to the surface at the Horsehays, in the centre of the coal-field. Owing to its rapid dip to the N.E. and small development, it has not been worked, and its further prolongation therefore is not positively known. Nevertheless there is no doubt that the carboniferous limestone immediately underlies the coal-measures from Little Wenlock to Lilleshall. (See Pl. XXXVI., Sections 5 to 7, 13 and 14.)

At Little Wenlock and Steeraways the upper beds of the limestone are very thin, argillaceous, and of a bluish gray colour. As the strata descend they become purer, but still contain much alumina and silica, which cause the lime, made from this rock, to set well under water. It is quarried for several iron furnaces. At the above places and at Lilleshall, the lime rock is subor-

* Its depth at this point is 150 yards.

dinate to beds of sandstone. At Lilleshall the deposit is much thicker than at Steeraways, being 60 yards, and it is also purer and generally of a lighter colour. The upper beds are dark gray and the lower nearly white; but they are all subcrystalline and hard. The partings between them are frequently composed of a red ochrey clay, which generally colours both the broken limestone and the workmen's dress. The following is a rough list of the strata at Lilleshall given me by Mr. Bolls:

Local Names.		Thickness. Yds.	Ft.	In.
1. White grit	Thinly laminated, light-coloured and mottled, coal-measure sandstones	variable.		
2. Gold lumber	Yellow clay	0	1	6
3. Grum	Nodular layers of crystalline limestone, with thin seams of clay; they become more compact in descending.	5	0	0
4. Slum	Red ochreous clay	0	1	6
5. Grum	Same as No. 3	0	1	6
6. Splother	Gray impure limestone	4	0	0
7. Slum	Red clay	0	0	9
8. Riding quarry	Gray limestone	1	1	6
9. Red limestone	Light red limestone?	1	1	6
10. Limestone	Gray limestone	3	0	0
11. Grit	Sandstone	20	0	0
12. White limestone	Light gray limestone	3	0	0
13. Hard grit ditto	Sandstone	40	0	0
14. Gray limestone	Gray limestone	3	0	0

The Grum is of a peculiar character, having rather the appearance of a conglomeratic, mechanical deposit, than the homogeneous composition usually prevalent in limestone rocks. The white bed (12.) is reckoned superior as a flux for the ironstone to any other in the country. The gray limestone (14.) is noted for forming a cement which hardens well under water. The average specific gravity of this stone is about 2·685.

The organic remains of this carboniferous limestone are neither so numerous nor so well preserved as those of the Wenlock rocks. This may be partly owing to the difference of mineralogical composition between the two formations. In the older deposit, the pure carbonate of lime of which it consists, has infiltrated into the minutest pores of the fossils; whilst at Steeraways and Lilleshall the great admixture of silica and alumina has given an earthy texture to all the organic remains. The fossils differ also considerably in their distribution. At Steeraways the *Leptæna* (Producta) *gigantea*, and *Lithostrotion floriforme* of Fleming, are abundant; while at Lilleshall, Crinoidea and Cyathophyllum are the most common; but *Leptæna hemispherica* is especially characteristic of the "grum." *

* For the age of this formation see the conclusion of the paper.

The following is a list of the more abundant fossils obtained by myself:

Bellerophon apertus, Sow.; *Leptæna hemispherica*, Sow.; *Leptæna gigantea*, Sow.; *Terebratula saccula*, Phil.; *Syringopora ramulosa*, Phil.; *Lithostrotion floriforme*, Fleming; *Cyathophyllum* ———; *Favosites? septosus*, Phil. (See also Appendix, List of Organic Remains).

In the foregoing pages, I have confined my observations to the range and structure of the formations underlying the coal-measures, deferring all remarks on the dislocations by which they are affected to a subsequent chapter, in which I purpose to describe the faults and their accompanying phenomena. The probable distance to which the different underlying formations may extend below the coal-measures, will be considered in the conclusion. I will now proceed to the examination of the coal-field of Coalbrook Dale—a field, characterized by the variety and singularity of its organic remains, as well as by the great disturbances which it has undergone.

COAL MEASURES.

Pl. XXXV. and XXXVI., figs. 1 to 14, and 16.

Owing to the hilly nature of the country, some excellent sections of the coal-measures are exhibited. On the sides of the deep gorge through which the Severn flows from the Iron Bridge to Bridgenorth, the coal-measures, the Wenlock limestone, and new red sandstone, are well exposed. At Woombridge, Lawley, and Coalmoor, are several open works of the Penneystone and sulphur coal. The flint-coal sandstone, so full of fine vegetable remains, is extensively quarried at Ketley. The lowest strata crop out in the side of the road at the top of the Dale, also at Steeraways, the Hatch, the Dunge, near Broseley, and in the various dingles south of the Severn. The upper strata are more rarely exposed. The heaps of the different ironstones at the pit's mouth afford, especially when long exposed, excellent opportunities for obtaining organic remains.

The measures are composed of the usual alternations of shales, sandstones, and coals, with, occasionally, subordinate calcareous beds. In the upper part of the series, unproductive marls, shales, and slightly calcareous, thick-bedded sandstones predominate; and in the lower part, shales containing ironstones, hard sandstones, sometimes conglomeratic, and numerous seams of coal. The colours of the upper strata are generally light gray, yellow, or red; some of the central beds are extremely dark, whilst the colours of the numerous lower sandstones are usually very light. Such are the general lithological characters; but they are subject to considerable local variations, which will be detailed hereafter.

It is difficult to state accurately the total thickness of the coal-measures, as there is no shaft section in which the entire series from the new red sand-

stone is exhibited. From the care with which Mr. Anstice has had the sections of the pits at Madeley taken, they afford the most correct information of the number of strata, and of the total thickness of the coal-measures. The details from which the following summaries have been deduced, were in part supplied by that gentleman.

	Depth.	No. of Strata.
Meadow Pits, Madeley	750 feet.	134
Hill's Lane	? 714	108

The following are sections in other parts of the coal-field :—

	Depth.	No. of Strata.	
Lightmoor	460	46	The minuter subdivisions in these sections not being generally given, as they are at Madeley, will account for the disproportion between the thickness and number of the strata; and, in one stratum, at one pit, may be included several of an adjoining pit.
Dawley.....	450	58	
Malinslee.....	560	51	
Woombridge	540	70	
New Hadley.....	440	57	
Donnington Wood ..	560	60	

Of the two deepest pits in the coal-field, I could obtain no sections. At the Woodhouse, near Priorslee, and at the Lodge Wood, pits have been sunk in which the clod coal* is 300 yards deep. As the higher strata in these works, and those of Madeley, are quite unproductive, and probably constitute the uppermost carboniferous series in this district, we may assume that the coal-measures have an average thickness of 1000 or 1100 feet, and consist, at the utmost, of ninety distinct strata†.

I endeavoured to obtain one or more shaft sections from every district in the field ‡; in many parts, however, no accounts have been kept, and I have had to depend upon the statements of the ground-bailiffs. From long practice, the memory of these superintendents is generally tenacious; but as it is liable to error, I have affixed a note of interrogation to all such sections; and to those which have appeared to me as very doubtful, I have attached two or more notes of interrogation : I have, however, taken every possible pains to ascertain the correctness of the accounts given to me. In most of these sections, except those at Madeley and a few other works, the thin, bituminous shales in contact with the coal are included in the thickness of the coal. At one pit, as already observed, several strata may be reckoned as one;

* The clod coal, which, from its regularity and persistence over the whole field, affords the best geological horizon, is, upon an average, about 60 feet above the base of the carboniferous series. (see Diagram, shaft sections, Pl. XXXVII.)

† The numerous thin local seams of coal and partings of clay laid down in the Madeley Pits are not here taken into account.

‡ See *postea* Appendix.

and at another pit, a stratum of sandstone may be subdivided into beds, according to the compactness of the different portions. When two beds of coal are separated by a layer of shale from only two to twelve inches, the layers are frequently omitted*.

This fact will readily be seen by an inspection of the shaft sections (see Appendix). The discrepancy from this and other causes is sometimes so great, that were it not for the Penneystone, clod coal, best coal, and one or two more beds, which serve as landmarks throughout the whole field, it would be difficult to recognize the connexion between the Donnington district and the Ma-

* As the colliers' names are retained in the shaft sections, an explanation of the most technical ones is necessary.

Local Names.	
Bannock	A slipperish, brownish gray clay.
Bass	Bituminous slate clay.
Binds	Fissile sandstone; sometimes a slate clay.
Calaminker	Mottled clay—generally red and yellow.
Carble	Shivery sandstones.
Clod	Shale; aspect dull and earthy.
Clunch	Clay, shale and marl; unctuous, smooth and shining.
Flint	Compact sandstone—freestone.
Heaving Earth	A clay which absorbs moisture, and swells by exposure to the atmosphere.
Linseed Earth	A fine, indurated, gray clay—generally a fire clay—very frequently contains a few ironstone nodules.
Measure	A term applied to all the workable strata, more particularly to the ironstone strata.
Pitcher Bass	Very bituminous slate clay.
Pitchy Rock	Rock impregnated with petroleum.
Pounstone	A stratum (generally of indurated clay) underlying a seam of coal.
Pricking	The thin layer of shale or clay in which the workmen undermine the coal or ironstone.
Quoice Neck	A shale which, when first exposed, exhibits shining and somewhat iridescent surfaces.
Riliff	Shivery sandstones.
Rotch	Hard mixed sandstone.
Slums	Coaly shale or clay.
Tator Butt	Fragile sandstone.
Espley Rock, Peldon Pebbly, Rough Rock, Pebbly Rock, Pimp Rock, Bull Rock	Conglomeratic beds, of various degrees of compactness and coarseness.
Die Earth	The formation upon which the coal-measures repose, and ceases, or dies out. Thus, at Madeley it is the Lower Ludlow Rock; at Lightmoor the Wenlock Shale, &c.

linslee, or between the Malinslee and the Madeley or the Broseley. The difference between the Amies and Donnington sections is still more striking, and placed side by side they appear totally distinct. (Diagram, Pl. XXXVII.) It is singular to observe the great and rapid variations in the importance and lithological character of the larger portion of the strata composing these coal-measures. One stratum will gradually disappear, whilst a thin one will rapidly acquire a thickness of several feet, and will again frequently wedge out. In some places, as at Priorslee, the clod, middle, and best coals are separated by only a few inches of shale, and can consequently be worked as one seam, and in the same level; whilst at New Hadley, Broseley, and other localities, they are separated by 4 to 10 feet of shale or sandstone. The Chance Penneystone, which is 8 feet thick at Woombridge, is unknown at Malinslee. In the former district 23 feet of sandstone and shale are interposed between the "white flat measure" and the "flint coal," whilst at Malinslee they are in immediate superposition: at the latter point there are 102 feet between the "brick measures" and the "double coal," though at Woombridge only 36 feet. The following table exhibits the thickness in feet of the strata between the Penneystone measure and the clod coal, commencing north and proceeding south, about 8 miles.

	Donnington	Hadley	Malinslee	Dawley	Lightmoor	Madeley	Broseley
Thickness of Strata between the Penneystone and Clod Coal..	44	36	32	54	60	72	94
Thickness of the Penneystone Measure.....	31	21	19	18	16	6	4

A singular instance of rapid variation occurs at Ketley and Arleston, in the upper and lower clunches. At Woombridge and New Hadley the thickness of these strata is 20 feet, whereas near the Ketley furnaces it amounts to 126 feet, and at Arleston to 120 feet; but at Lawley it again decreases to 21 feet, and at Little Wenlock to 15 feet. Amidst all these indications of rapid changes, the persistence over large areas of the lower coal-beds, especially the clod coal, is remarkable. The upper coals are, as before stated, more irregular in thickness and extent, though far more constant in their range, than the other strata. In the old Park, an instance, however, occurred of a bed of coal six feet thick gradually thinning off, and extending through an area of only 300 yards by 40 yards.

It would be an almost impracticable task to enumerate all the changes exhibited in every part of the field; I have therefore attempted to form a diagram (Pl. XXXVII.) which connects and dovetails the principal sections of the coal-field from Donnington to Caughley; and an inspection of it may convey a clearer idea of the structure of the coal formation than could be derived from a

lengthened description. The vertical scale is necessarily much exaggerated in order to show each stratum, and to avoid too great an extension. The changes in lithological characters also are partially illustrated in the same diagram.

It may be mentioned that rapid changes in thickness and composition are generally concomitants. The upper and lower clunches of the northern and central districts pass, as they expand* in their range southward, into hard shales, and eventually into sandstones, with a few subordinate beds of shale. The strata of sandstones, marls, clays, and shales, indeed rarely maintain the same appearance for a mile, and frequently differ considerably in the space of twenty yards. The shales are however far more constant in composition than the sandstones, which vary incessantly, passing from a fine-grained into a very coarse rock or into a more or less compact shale. For example, the best coal rock at the Meadow Madeley pits changes from a light buff-coloured sandstone into a hard dark gray shale. At Ketley, the sandstone overlying the Penneystone is of a bright ochreous colour, and at Broseley it is quite white. The curious phenomenon locally called "Symon fault" is another instance in point. This apparent fault is occasioned by the gradual, but complete substitution of the coal by clay, shale, or sandstone. The coal is at first deteriorated by a slight admixture of one of these substances, the proportion of which rapidly increases, until it entirely replaces the coal. This phenomenon is of common occurrence in the neighbourhood of Broseley and Caughley, and occasionally at Madeley and Priorslee. The alteration in the coal varies in extent from ten to five hundred yards. At Langley, a sandy "Symon fault" occurs in the Penneystone measure, when a great increase in the number and variety of the organic remains was observable. Another great change in lithological characters, and in the thickness of the strata, occurs between Lightmoor and Madeley. In all the series above the flint coal it is difficult to trace the connexion between the two districts. (See Diagram.) Notwithstanding these frequent changes, the coal-measures, as mentioned at the commencement of the chapter, preserve a certain general arrangement.

A very important example of this phenomenon is exhibited at Malinslee. The upper strata are the first affected, but the altered structure gradually pervades the whole of the measures, as they trend eastward. The change is apparently produced by an admixture of red and yellow clay, marl and sand, locally called "Calaminker". The upper coals and ironstones are replaced by beds of this character immediately east of Malinslee, the change in the flint coal shortly follows, then the gray and uniformly thick Penneystone stratum assumes the appearance of a mottled red shale, and finally the clod and lower coals vanish at Randley Wood, half a mile east of where the change commences in the upper strata. A somewhat similar and equally remarkable alteration occurs in the northern extremity of the field, commencing between Donnington and Munton. The upper strata there pass into thick irregular beds of concretionary red and light greenish conglomerate, containing a few very thin layers of coal, and some subordinate beds of shale. The deeper strata are however less affected, and at a trial pit sunk near Lilleshall Hall, the strata from the clod coal up to the top of the flint rock above the Penneystone, corresponded

* Excepting in their temporary expansion at Ketley and Arleston.

precisely with the undisturbed measures of Donnington, but all the coal and ironstone above that stratum had vanished. (See shaft section, Diagram, Pl. XXXVII.).

The surfaces of some of the strata are furrowed and waved, and saddle-shaped ridges, two to four feet in height and several yards in length, sometimes exist on the surface of the shales underlying the coal-beds; but they gradually disappear in the overlying strata. In the sandstone, especially in the coarser beds, the under surface is in places very uneven, filling up hollows and grooves in the subjacent shale or coal, and resulting apparently from the abrading action of the water which deposited the sandstone. In the shale roof of some coals are occasionally found singular misshaped conical masses, which from their smooth surface fall out, to the annoyance of the workmen, as soon as the supporting coal is removed. They are traversed by divisional and slightly concave planes at right angles to their axes, but otherwise exhibit no external or internal structure. They are formed of the same substance as their matrix, from which they are sometimes separated by a thin parting of coal. The name given to them is "pot-holes" or "hatter-blocks." Their height is generally two or three feet, and the diameter at the base equals one-third or half of the height.

Shales, sometimes slightly micaceous, are not of frequent occurrence, but hard indurated clays are common, and often contain ironstone nodules. The argillaceous strata predominate in the north of the coal-field, and sandstones in the south. The latter are occasionally micaceous and fissile, and sometimes form thick-bedded freestones, but at other times are coarse-grained and conglomeratic. The imbedded pebbles almost invariably consist of milk-white quartz, but a few of a red colour are associated with them, and the matrix apparently consists of the same materials finely comminuted. Partings, filaments, and *roundish lumps* of coal, are common in the upper sandstones. Petroleum impregnates many of the central sandstones; and salt-water pervades some of the sandstone strata. Dr. Townson says, "In the neighbourhood of this tar spring (at Madeley), several springs of salt-water have been found, but none of sufficient strength to be worth working. The water which exudes from the flint coal in some works in the parish of Madeley, is likewise salt; and in the adjoining parish of Broseley, there was formerly a salt-work, where salt is said to have been made from water taken out of the coal-pits*."

Nos. 34. and 51. in the section of the Hill's Lane pits, are beds of an impure calcareous conglomerate; but as they are nowhere exposed, and were

* Townson's Tracts, p. 176.

only to be judged of by hand-specimens, I could not ascertain whether any fossils existed in them.

A gray and brownish very hard limestone, with a conchoidal fracture, and varying from one to two yards in thickness, crops out at Tasley near Bridgenorth. The lime made from it, is in general applicable to agricultural purposes only, but in some cases it is well adapted for a water cement. At the Amies it apparently consists of fragments of a gray limestone imbedded in a whitish calcareous paste. This bed of limestone was first noticed by Mr. Murchison in a memoir read before this Society in 1834, and shown by him from its organic remains to be of freshwater origin. He has detected the band, at intervals, along a devious outline extending to the edge of the Breddin Hills, but always in the same geological horizon. It is but lately, that I have been enabled to ascertain its true position in the Coalbrook Dale field, as it had hitherto been explored at its outcrop only, where but a few feet of clay or marl overlie it.

In September 1836, I found at the mouth of a pit*, then sinking between the Amies and the Tuckiss, a considerable quantity of the same limestone†. The bed was about 4 feet thick, 90 yards from the surface, and 10 yards above a sulphur coal, about 125 feet above the clod coal, or only 170 feet from the base of the formation; but this part of the field being apparently of littoral formation, the connexion of the strata between this locality and those where marine remains occur‡ is not yet clearly ascertained, for I have been unable distinctly to detect this band of limestone on the north of the Severn. Nevertheless, by tracing the prolongation of the bed by means of a few of the associated strata, its equivalent in other parts of the coal-field may be approximated to. Accordingly, at New Hadley and Woombridge, the place which this freshwater stratum should hold may be somewhere about that occupied by the marine deposit of Chance Penneystone.

A few of the thicker lower sandstones are extensively quarried for building materials; the principal so employed being those above the little flint coal, the Penneystone, the flint coal, and ball-stone. The first makes the best hearthstones for the iron furnaces. The beds of clay are numerous and valuable. The Shropshire fire-clay vies with that of Stourbridge; and its bricks are sent to all parts of the kingdom. Many of the "Pounstones" form good fire bricks. A peculiar difference marks two of the ironstone shales. The shale in which the Penneystone is imbedded, is extremely injurious to

* See section of Amies pit, Diagram, Pl. XXXVII.

† Its specific gravity is 2·65.

‡ It is to be observed that in no instance has the Penneystone with its marine reliquiæ been found immediately underlying this freshwater limestone.

vegetation, its mounds remaining for years without a blade of grass; whereas the shale of the ballstone forms a very productive soil, and is used as a manure. In the former marine, and in the latter, only vegetable remains are found.

For further explanation of the mineralogical characters of the different strata, I must refer to the explanatory sections of Woombridge pit (Appendix A.) by Dr. Townson, and that of the Hill's Lane pits, Madeley, by myself (Appendix).

In the upper measures, the coal seams are usually thin, distant and irregular in their deposition; whereas, in the lower, they are thick and persistent over the whole field. The average thickness of the principal coal-beds is about 3 feet; and the number of the seams varies from 7 to 22. The following table exhibits the total thickness and number of the coal-beds at each place respectively.

		Total Thickness.	No. of Beds.
North to South.	Donnington	55 feet.	19
	Woombridge	52	18
	New Hadley	46	16
	Malinslee	36	15
	Dawley	43	17
	Lightmoor	40	17
	Madeley	33	22
	Broseley	24	10
	Amies	16	7

In these localities the productive coal-measures are fully developed, and consequently the difference of total thickness does not arise from the cropping out at one place of beds which exist at another. The Madeley sections have been so carefully made, that the thinnest layer has been recorded, which is not the case elsewhere. Hence the great difference in the number of the beds. We see from the above table, that the number, and especially the total thickness of the coal seams, decreases to the south. The same phenomenon also occurs, as will presently be shown, in the ironstone measures.

The coals of this district are generally of the variety called slate coal. Some of the upper seams, especially the fungous coal, contain a large proportion of mineral charcoal. Foliated coal forms several of the thin upper seams, and particularly the sulphur coal, underlying the Penneystone. This coal often breaks into very regular cubical fragments, and has a brilliant lustre. Cannel coal is of rare occurrence. At Madeley several tons of it were found in the middle of the flint coal, forming a layer 8 inches thick, which gradually thinned out.

Many of the coals contain so much sulphuret of iron, that they can be used only for making lime, as the "sulphur coal" below the Penneystone, which is, in other respects, a fine seam. These pyritous beds are called sulphur or stinking coals, and are distinguished by the lustre and sharpness of their fracture, their greater specific gravity, and by their unpleasant odour while burning.

Sometimes iron pyrites forms layers three or four inches thick; at other times it is mixed with coal in minute, invisible particles. The presence of this mineral renders the coal unfit for the reducing of the ironstone. At Kingslow, the "sulphur coal", which contains much black and brown mineral charcoal, is often beautifully iridescent*.

Vegetable impressions may occasionally be detected in some of the coals; and I have a specimen of the "best coal" which exhibits a very sharp and distinct impression of a portion of a palm-leaf. Imperfect remains of vegetables, in the state of charcoal, are not uncommon, especially in the "fungous coal", of which they sometimes constitute the larger portion.

The "clod coal" is the best in the district, both for general use and for the iron furnaces. The "middle and best, or Randle coals", which almost immediately overlie it, are also good coals, but are rarely fit for the manufacture of iron. The "fungous coal", which is confined to the north of the field, is also excellent for every purpose. The "top and double coals" are equally valuable. The "flint coal" is good and serviceable, but cannot be used in the iron furnaces; neither can the "little flint coal", which is much worked in the southern districts, but it is not equally good in the north of the coal-field †. All the coals have a distinct line of cleavage, at right angles to which the miners always proceed when possible. These joints are vertical to the lamination, and are invariably W.N.W. and E.S.E. An imperfect set of joints runs at right angles to this system. Sometimes, however, as in the "sulphur coal" at Ketley Bank, both are equally developed.

Iron is abundantly diffused throughout the whole of the coal-measures, but it prevails in some strata more than in others. Almost all the sandstones are tinged, spotted, or striped by the peroxide of iron, which hardens the rock; and consequently, when its surface is exposed to the atmosphere, these ferruginous patches stand out in relief.

In the shale beds, in which it occurs in the greatest abundance, it consists of argillaceous carbonate of iron, in flattish nodules, of variable size, form, and specific gravity. All the workable ores are procured from these beds, with the exception of the "Crawstone", or lowest measure, which forms irregular large masses in a finely-grained sandstone. This measure is of much better quality in the southern than in the northern division of the coal-field.

Proceeding upwards the "Penneystone" nodules are generally small, flat, and smooth; but they increase in size and number as they approach the top of the stratum, where they not unfrequently form a capping of solid layers.

The "white flats" are in a hard shale, and consist of small, light-coloured, and rather rough nodules.

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* I have made a proximate analysis of the principal coals of Coalbrook Dale, and found that 100 parts of coal consist of the following component parts:

Names and Locality.	Volatile Substances.	Carbon.	Ashes.	Colour of Ashes.	Sp. gra.
Fungous coal.—Donnington..	34·8	63·8	1·4	White tinged brown.	1·245
Top coal.—Ditto	37·1	62·1	0·8	Very light brown.	1·267
Flint coal.—Madeley	34·6	64·9	0·5	Fawn.	1·269
Sulphur coal.—Ketley	41·1	56·1	2·8	Brown.	1·292
Best coal.—Madeley	34·3	64·4	1·3	Light dirty yellow.	1·273
Clod coal.—Ditto	37·3	62·7	1·0	Ditto darker.	1·264
Little flint-coal.—Broseley ..	38·3	61·1	0·9	Burnt umber.	?

† See Dr. Townson's Descriptions.

The " blue flat" is a large, misshapen, very fossiliferous ironstone, imbedded in a very dark bluish shale.

The " chancestone" is an irregular, thickish layer, capping the yard-coal, to which it adhere It is of local occurrence.—See New Hadley.

The " yellowstone," so called from its external colour, consists of small, very rough, and lumpy nodules, frequently with a conchoidal fracture.

The " ballstones" generally form two or three layers of large, smooth nodules, imbedded in a light-coloured shale. It is not known by this name south of Ketley.

The " brickman's measure" consists of two or three layers of ironstone, which break into nearly regular parallelopipeds resembling bricks.

The " blackstone" is composed of small and lumpy nodules, with a black, shining coating, and a characteristic conchoidal fracture. They are imbedded in a tough, dark clay, and are not known south of Malinslee.

The " Ragged Robins" is a very irregular ore, and is occasionally found in the argillaceous sandstone underlying the fungous coal, as at Ketley and New Hadley.

The nodules of " Chance Penneystone" are small, but smooth and numerous, and are also not known south of New Hadley.

The above are the beds usually worked in different parts of the coal-field, the higher measures having a very limited range.

The following tables will show that the number and thickness of the workable measures are much greater in the northern than in the southern part of the field.

Ironstone Strata.

		Number.	Thickness.
North to South.	Donnington	7	72
	Woombridge	8	80
	New Hadley	6	40
	Malinslee	5	38
	Dawley	4	34
	Lightmoor	3	24
	Madeley	3	14
	Broseley	2	8
	South of Ditto	1	3

The ironstones thin out in their range southward in descending order; thus the Chance Penneystone first disappears, then the Blackstone, and others after; so that at Broseley we find only the Penneystone and Crawstone, and to the south of Broseley the Crawstone by itself.

Mr. Smith* calculates the produce of ironstone per square yard of surface measure to be as follows:

	Thickness of Stratum. Ft.	Quantity of Ironstone. Ton.	Cwt.	Qr.
Chance Penneystone	6	0	4	0
Blackstone	4	0	8	0
Brick-measure	16	0	6	0
Ballstone	9	0	5	0
Yellowstone	9	0	5	0
Blue flats	6	0	6	0
White flats	6	0	4	0
Penneystone	24	1	4	0
	80	3	2	0

* Miner's Guide. p. 128 to 132.

The same author makes the average produce per acre as follows:

Coals	31,944 tons.
Slack (small coal)	7,986 ..
Ironstone	13,794 ..

These calculations were made from data obtained in Woombridge, and are consequently not applicable to other parts of the coal-field. In addition to these regular measures large nodules of ironstone are disseminated through various parts of the strata. The ironstone of the clod coal passes sometimes into a thin layer of solid ironstone. Some of the shales of the lower series, especially the bituminous shale overlying the little-flint coal in Broseley and Caughley parishes, contain occasionally very large septariated nodules of ironstone, often 6 or 7 feet in diameter and 1 to 2 feet thick. A singular conglomerate of ironstone caps the Penneystone measure at Madeley and Lightmoor, and now and then in other localities. It forms a layer from an inch to a foot thick, consisting of numerous small grains of milk-white quartz and a few small rolled pebbles of ironstone and traces of trap rocks, imbedded in a matrix of ironstone.

At Woombridge and in its neighbourhood, nodules, from 1 to 4 feet in diameter and 1 to 2 thick, of calcareous ironstone, inclosing curlstone, form the upper layer of the Penneystone measure. Upon breaking the nodules, the apices of the cones of curlstone are found generally attached to the upper and lower surfaces of the crust of the nodule, whilst the bases of the cone face and nearly touch each other. Some portions of the curlstone when calcined, form excellent red ochre.

The composition of the ironstones varies, but the average produce is about 33 per cent. Two or more different ores are generally smelted together. According to Mr. Anstice, the following is the average proportion of fuel, flux, and ore, necessary to make one ton of pig iron: Coal, 4 tons; limestone, 1 ton; raw ironstone, 3 tons. The loss of weight by calcination is about 25 per cent.

For an account of the extraneous minerals found in the ironstone nodules, see Appendix B.

The following average specific gravities of the principal ironstones, I have deduced from several experiments:

Blackstone—*Donnington*	3·573	Penneystone—*Madeley and Broseley*	3·606
Brickmeasure—*Woombridge*	3·304	Crawstone—*Ditto*	3·687
Ballstone—*Ditto*	3·418	Large ironstone nodules overlying the little flint coal at the Amies	3·651
White Flat—*Ketley*	3·501		
Penneystone—*Priorslee*	3·477		

Petroleum abounds in the central and upper portions of the field. The well-known tar spring at Coalport, which had its rise in one of the thick sandstones of the central series, formerly yielded nearly 1000 gallons a week; but it now produces only a few gallons in the same time. In sinking a shaft at Priorslee, the 20-yard rock was so charged with petroleum, that the shaft was converted into a tar well. The mineral is drawn up in a bucket, and kept in large cisterns; but the supply has much decreased. In Tarbet's Dingle is a spring of water, upon the surface of which floats a small quantity of petroleum. It formerly yielded two or three gallons a day. In a pit at the top of the same dingle, petroleum exuded in so great abundance from every crevice in the "little coal," and from the shale forming the roof, that the colliers were obliged, in the latter case, to have large plates of iron suspended over them. This inconvenience was, however, of no great extent. Similar cases have occurred in working the flint coal in some of the Dawley pits. In the roofs of

the clod and best coal, I have frequently seen it in smaller quantities. More rarely, petroleum is found in cavities in the Penneystone nodules.

Carburetted hydrogen gas is evolved in larger quantities in the deep-seated coals, and in less abundance in those which are nearer the surface, and, consequently, the deep works at Dawley, Malinslee, Priorslee, &c., suffer much more from this gas than the works at Lawley, Ketley Hill, &c.* In the first-mentioned districts the disengagement of the gas from the pores and fissures in the clod, best and sill coals, especially at the commencement of a new work, is considerable, but still much less than is given off under similar circumstances in the Newcastle and some other coal fields. In walking along the wall of the coal, the gas may be constantly felt issuing from the small crevices. It is worthy of remark, that the evolution of the gas always greatly increases upon approaching the Lightmoor and other large faults; near which masses of coal are frequently blown off the bed, with loud detonations. Now, may not this larger accumulation of gas in the vicinity of the faults be owing to the powerful action which accompanied their formation?

To account for the enormous quantity of gas evolved in the Newcastle coal-field, Mr. William Hutton made a series of interesting microscopic investigations, and ascertained that the coal contained numerous small cells, in which he supposes the gas was originally confined in a fluid state; and that when the great superincumbent pressure is decreased in the progress of the works, the elasticity of the fluid immediately causes it to assume its gaseous form—the great and sudden expansion being accompanied with loud detonations†.

Carbonic acid gas is more rarely met with, and chiefly in the old workings. Near the roof of a small excavation in a pit at Caughley is a narrow opening, through which a stream constantly flows, and descends to the floor, where it forms a stratum from eight to twelve inches thick, the ventilation of the pit preventing its further accumulation; but a small shaft in the same chamber is completely filled with it. This great supply is probably derived from some of the neighbouring old works,—the gas passing through fissures in the rocks. Carbonic acid is seldom present in any quantity during the working of a pit; but in many, when abandoned, the atmospheric air is soon expelled by it.

Note.

Coalbrook Dale has been long celebrated for its iron-works, which once produced the best iron in England; but it is not known at what period the manufactory of this metal was there commenced. From the extent of the outcrops of the Crawstone and Penneystone ironstone measures, and of the little flint, clod, best, sill, sulphur, and big-flint coals, no portion of the country could offer greater facilities for procuring an easy and large supply of ore, flux, and fuel. In many parts of the coal-field, where the necessary materials are now exhausted, are large heaps of slags and cinders, for which even tradition does not assign an origin‡.

* To the escape of this gas, from one of the deep-seated coals, through some small crack in the superincumbent strata, no doubt is to be attributed the phenomenon of the celebrated burning well at Broseley, discovered in the beginning of the last century, and destroyed by the sinking of an adjoining coal pit in 1755.

† Proceedings Geological Society.—Vol. i. p. 415.

‡ A few years since were found in a coal pit, 80 yards deep, and on the banks of the Severn,

Camden states, that before his time, coal and iron were worked at the Oaken Gates. As this place, the Usocona of the Romans, is situated at the foot of a hill, upon the sides of which the Penneystone measure and the flint coal crop out, it is very probable, that these minerals were worked during the occupation of Britain by the Romans, who had also another important station at Uriconium, now Wroxeter, opposite to that on which the Oaken Gates are situated.

It is certain however that, of late years, the collieries have been so industriously and generally worked, that almost all the best seams, both of coal and iron, to the west of the Lightmoor fault, and south of Ketley, are nearly exhausted. To the south of the Severn, in the vicinity of Broseley, there were formerly eight or nine furnaces; but they are now all blown out, for want, principally, of the proper description of fuel. A valuable supply of coal and ironstone, however, yet remains in the districts east of the Lightmoor fault, and at Donnington. Still, from the limited extent of the coal-field, as now known, and from the great activity with which it is worked, it appears probable, that the materials for the manufacture of iron will be exhausted in a very few generations. The iron masters must then continue their works under the new red sandstone, beneath which it is to be hoped that they will find, although at a great depth, a new and abundant supply.

Organic Remains of the Coal-Measures. (Plates XXXVIII. to XLI.)

The paper on the Ganister Coal Series in Yorkshire, by Mr. J. Phillips*, contains an interesting account of numerous marine remains found in those coal-measures. While reading that paper, I was struck with the analogy between the Yorkshire field and that of Coalbrook Dale, similar alternation of beds containing marine and fresh-water exuviæ occurring in both localities. These phenomena are supposed by Mr. Phillips "to indicate a periodical return of the marine element into its ancient receptacle, after it had been for some time occupied by fresh water, and its few inhabitants." I am inclined, however, to consider, that the measures of the Coalbrook Dale field were deposited in an estuary, into which flowed a great river; that the latter, during periods of tranquillity, carried down the silt forming the present beds of shale, enclosing, at the same time, the marine inhabitants of the estuary; and that during floods, the river drifted along vast quantities of uprooted plants

several implements used in mining, evidently of considerable antiquity; they were all constructed very rudely of wood, merely edged or bound with sheet iron.

* Phil. Mag., Nov. 1832, Vol. 12., p. 349. The occurrence of these marine remains near Halifax was noticed by the late Mr. James Sowerby. See Min. Con., *Ammonites Listeri*, *Pecten papyraceus*, and *Orthoceras Steinhaueri*.

with fluviatile shells, and thus accumulated those strata, principally of sandstone, which are characterised peculiarly by terrestrial or fresh-water remains.

This subject will be discussed more fully in the conclusion; and I proceed to a particular account of the zoological and botanical reliquiæ of the different beds. (See also Appendix C., list of organic remains.)

Upon the hard sandstone conglomerate, which forms the lowest stratum of the coal-measures, reposes a seam of coal. See Diagram, Pl. XXXVII.

To this succeeds thin beds of sandstone and shale; and in one of the latter occurs, at Wimsey Styches and Caughley pits, Madeley parish, the "new mine ironstone," which contains a very few vegetable remains and Unios.

A few yards higher is a series of sandstone strata, characterised by numerous casts and impressions of the *Stigmaria ficoides*; and it also contains Calamites and Sigillariæ. About the centre of these strata is a bed of whitish sandstone, with ironstone, called "the Crawstone," which abounds with the remains of the *Stigmaria ficoides*, some ten inches in diameter; and, occasionally, with casts of Unios, remarkable for their preservation and smooth surface*. Many of the Stigmaria found at New Lawley, exhibit the central pith-tube structure beautifully preserved. It was in a specimen from this locality that the singular anatomy of the plant was detected by Professor Lindley†.

A few feet above the crawstone is the little-flint coal, the only seam which in any part of the coal-field occurs between two strata of sandstone. A singular phenomenon is frequently presented by this bed. Having been informed that at Madeley, Broseley, and elsewhere, the coal is occasionally so pebbly that it cannot be used, I inspected the bed, and I found that it was traversed horizontally in all parts by small flattened tubes of white sandstone, proceeding from stems of the *Stigmaria ficoides*, and imbedded in the coal. The length of these bodies, or casts of leaves, I could not ascertain; but it was evident, from the condition of the stem and from the leaves being generally attached, that the plant could not have been much disturbed from its original position. The stems are generally horizontal, or gently inclined, and slightly flattened; and the leaves, which proceed from them at right angles, or nearly so, are very little compressed between the laminæ of the coal. The sandstone, which has replaced the stem, bark, and leaves, is finely grained, and remarkably white. How to account for its infiltration into the body of plants placed in a thick seam of coal offers an interesting inquiry‡. In the roof of the coal, impressions of *Stigmaria ficoides* are common, with a few Calamites.

To this coal succeed thick sandstones, with a few similar vegetable casts and impressions.

In the thin beds of shale and clay separating the clod, randle, sill, and best coals, which overlie the thick sandstones, the multitude of vegetable impressions is very surprising. They lie horizontally, and in all directions. Amongst them are Poacites, Calamites, Lepidodendra, Sigillariæ, and a few Stigmaria; but the characteristics are Sphenopteris, Neuropteris, and Sigillariæ, some of

* Hitherto found only at Madeley and Broseley.

† Fossil Flora, Plate 166.

‡ The entangled Stigmaria may have decayed subsequent to the partial consolidation of the coal; and through small crevices in the coal, or the narrow tubes of the long leaflets, the fine overlying sand may have been forced, by the gradually increasing superincumbent pressure; the continuation of which would, by further compressing the stratum of coal, slightly flatten the imbedded casts.

the last being 25 feet long and 5 feet broad. I procured in these beds only one imperfect cast of an univalve, resembling the Bellerophon found in the Penneystone.

In the sandstone and shale above the best coal at the Birch leasow pits, Broseley, casts and impressions of vegetables are so numerous as to divide the sandstone into thin laminæ, which are easily separated. At Blissers' Hill pit, Madeley, and at the Holywell pits, Malinslee, I also saw some very large casts, the terminations of which I could in no instance discover. Upon several of the impressions of the delicate Sphenopteris imbedded in the rock above the best coal at Broseley, the vegetable tissue of the leaves is preserved, and presents a thin, brown, semi-transparent, and elastic filament*. Mr. J. Phillips has shown me vegetable remains in the same state from the oolitic series in Yorkshire. Similar fossils, but in less abundance, characterise the strata up to the Penneystone.

The organic remains contained in this bed of ironstone, are tolerably numerous† and well preserved; and are of the greatest geological importance, as marine animal remains largely preponderate. Fragments of a few stems of plants, from two to three inches long and from half an inch to an inch in diameter, are the only vegetable reliquiæ found in this stratum. The external characters are entirely destroyed, but the cellular texture and the fibres are preserved in the state of soft brown lignite. These remains are often studded with beautiful crystals of blende and carbonate of lime, and are enclosed in the nodules of ironstone.

The characteristic marine fossil is the *Leptæna* (Producta) *scabricula*, which is abundant, and is well known as a mountain limestone fossil; the *Spirifer bisulcatus* likewise occurs frequently. Several species of Nautilus, Bellerophon, Conularia, Pecten, Orbicula, Unio, Terebratula, Nucula, Globulus, Lingula, and other shells (Appendix C.), associated with scales and bones of the *Megalichthys Hibberti*, and the *Gyracanthus formosus*; likewise remains of Crustacea, new species of Trilobites, and Crinoidea and Coprolites. In the centre of almost every ironstone nodule at Broseley is a dark-coloured, irregularly-shaped spot, which rarely exhibits any traces of organization; but the careful examination of an extensive suite of the nodules shows, that the greater number of these remains are referable to Conulariæ, a few to Coprolites, and a less number to the animal matter of the Orbicula. Conulariæ abound in this part of the coal-field, though not so plentifully as at Madeley, and are more rarely found at Hadley, Woombridge, and Donnington. They vary from a quarter of an inch to two inches in length, and the breadth at the larger end is about a quarter of the length. In none of the numerous specimens which I have examined, could I find any traces of a septum. In two, however, I discovered an apparently osseous structure; white carbonate of lime having infiltrated into the pores, whilst the organic matter remains nearly unaltered, but of a dark brown or black colour. Mr. J. De Carl Sowerby also pointed out to me a singular character. The striæ of some specimens are notched by a set of transverse small furrows, whilst in others the striæ are perfectly smooth. This difference in structure he found in examining an ironstone specimen, to arise from the presence or absence of a thin, dark-brown skin or covering, of which the interior striæ are smooth, and the exterior denticulated or notched (see Plate XL.). The dark spots in the ironstone are not

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* In the same rock, small dark-brown round flat seed vessels, rather less in size than a spangle, and retaining a nearly unaltered vegetable texture, frequently abound.

† Like, however, the organic remains of the chalk, they occur detached, and require a careful search, unlike those which are heaped together in patches, bands, or beds, as the unios over the flint coal at Woombridge, and as the vegetable reliquiæ generally.

always confined to the size of the Conulariæ, but are frequently larger, and when such specimens can be separated from the matrix, they are generally found to consist of an oval body, without any traces of external markings, the larger axis being traversed by a Conularia, the apex of which sometimes slightly protrudes. Whether this body be part of the Conularia, I cannot decide; but its black colour indicates animal matter. Another characteristic fossil of the Penneystone measure is the *Orbicula reflexa*, of which several specimens are frequently found in one nodule. The exterior of the shell, which is either black or speckled white and brown, generally retains its beautiful lustre, but the organic matter is almost entirely replaced by the substance of the matrix—except in a very few instances, where a fine white, very delicately striated shell remains. Several species of Unio, often of a large size, occur in the measure. The Bellerophon is rare, except at Langley, where some of the large thin flakes of the ironstone are full of them. Nautili are common; but univalves are rare, (see Appendix, list of organic remains). Mr. Anstice has lately obtained portions of a column of *Cyathocrinites quinquangularis* in a Penneystone nodule at Madeley. The fragments in the centre of the nodule consist entirely of the substance of the matrix; but although no organic matter remains, the surface of the encrinal column and its plates exhibit a vitreous lustre similar to that of the facets of crystals, and like them, separating easily in the direction of the natural surfaces. When the fossil occurs upon the outside of the stone, no such appearance is exhibited. At the Horsehay pits, I have since found numerous specimens of the same Cyathocrinites; but in this case, the organic matter is replaced by light yellow, earthy carbonate of iron. The presence of sauroid fishes in this deposit is of considerable interest. The remains of these animals have been long noticed in the coal-measures, but it is to the recent labours of Dr. Hibbert-Ware* and M. Agassiz† that we are indebted for the determination of their nature.

In the first volume of the Zoological Journal, Mr. Sowerby figured and briefly described the ray of the *Gyracanthus formosus*; but he confessed that he was unable to refer it to any known genus. This specimen was from the Newcastle coal-field; and in the Museum of that town, Mr. Hutton showed me several similar rays. Mr. Anstice has had fossils of the same nature in his collection for many years. Dr. Hibbert-Ware in his able memoir says, "the limestone of Burdiehouse entombs thorny rays of immense magnitude, and most beautifully configurated, which it is impossible to contemplate without amazement. M. Agassiz proposes to name the fish to which these rays belong, the *Gyracanthus formosus*." In the shale of the Penneystone, but also upon the exterior of the ironstone nodules, are occasionally found the angular scales of that remarkable sauroid fish the *Megalichthys Hibberti*. The scales differ slightly from those which I have seen at Burdiehouse, their lustre externally being greater, and their colour much darker. Dr. Hibbert-Ware states that "one description of scales (of the *Megalichthys*) exhibits a coating of enamel of a nut-brown colour, and often of the most brilliant lustre imaginable. These scales are of various forms, though generally angular. A most curious character is the punctured surface which many of them display, a character which I have traced, though in a less prevalent degree, in the scales of the recent crocodile." Some of the large plates of the head are found at Madeley in a perfect state, and are mottled dark brownish grey, (see Plate XLI., fig. 10, 11.); the scales of the body are rarely in position, but I have met with one specimen in which several of them were continuous. This specimen also exhibits a few of the vertebræ, which are about three-quarters of an inch in diameter, and concave on both sides; the last-mentioned remains are very scarce‡.

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* Trans. Royal Society of Edinburgh, vol. XIII. † Poisson's Fossiles, tome ii., p. 87.

‡ Mr. Anstice's collection contains a beautiful series of the organic remains of this stratum.

An interesting phenomenon in the distribution of the animal reliquiæ in the Penneystone measure is observable at Langley. I had collected from other localities during three summers, a large number of Leptænæ, Spirifers, Orbiculæ, Conulariæ, and Nautili; and Mr. Anstice had found one specimen of a Cyathocrinites and a few scales of the Megalichthys and Gyracanthus, but in the deep works at Langley, the Penneystone measure, which is usually very regular in its character, was in one place much changed by an admixture of sand, and the ironstone nodules became lumpy, less numerous, and bad; and were accompanied by a remarkable increase in the number and variety of the organic remains; including all the before-mentioned species, together with species of Bellerophon, Nautilus, Nucula, Lingula, Crinoidea, &c. Unfortunately, the quality of the ironstone was so much deteriorated, that that part of the work was soon abandoned. A singular diminution, and, finally, a total absence of fossils, occurs in this stratum in its range northward. (See Diagram, Pl. XXXVII.)

Above the Penneystone, south of Lightmore, no marine remains have been found.

The Penney-ironstone measure is immediately succeeded by a stratum of a fine-grained sandstone, generally ferruginous, and varying from 5 to 10 yards in thickness; but the fossils, unlike those of the subjacent bed, consist of a most luxuriant land vegetation, including numerous species of Calamites, Sigillaria, Lepidodendron, and Stigmaria. These remains are most frequently found in the partings of the rock, and generally lie horizontally, but in all directions. As usual, the cast is formed of the substance of the matrix, and it rarely, if ever, possesses any traces of vegetable texture; but the exterior bark is frequently replaced by a thin coating of fine coal. Calamites of several species constitute the prevailing fossils; and they are generally from half an inch to 4 inches in diameter and from 1 foot to 10 feet in length; yet owing to their extreme brittleness when first exposed, they are difficult to preserve entire. Sigillariæ are also common, some of them being of a very large size. One fine specimen, in a quarry near Ketley, measured 10 feet in circumference. It was truncated at the parting of the strata about a foot above the root, which consisted of four tapering prolongations, each about 4 feet long. The markings on the surface were nearly obliterated, and the species consequently could not be determined. Specimens of this size, I have always found similarly placed, and universally truncated. They may be observed in the "cow wood" and other quarries of that district, in the sandstones of the "clod coal poundstone" at Castle Green, and in the same measures in the Blisses Hill pits at Madeley. Imperfect impressions of the leaflets of Stigmariæ and Lepidodendra can generally be traced. A few varieties of dicotyledonous wood also occur.

Immediately upon this sandstone reposes the flint coal, in which vegetable impressions are not uncommon. In a pit at Dawley, I found a large upright stem in a similar condition to that of the fossil tree of Cragleith. Its diameter was 1 foot and its height 3 feet; and it was truncated at both ends. The bark, which was replaced by coal, about a quarter of an inch thick, exhibited no distinct marking. The internal structure was that of coniferous wood, somewhat resembling the *Pinites Withami*.

In the hard bituminous shale which in some parts of the field overlies the flint coal, are several bands full of a crushed bivalve shell, and belonging apparently to the genus Unio; scales of a Hybodus? and other fishes occur, though rarely.

To this generally succeeds a bed of hard micaceous shale containing a layer of ironstone nodules, called the white flats, in which are imbedded some very interesting fossils. The characteristic plants are Lycopodiaceæ and Equisetaceæ; but associated with them are considerable quantities of two or three species of Unio. Scales and bones of *Megalichthys Hibbertii*, and *Gyracanthus formosus*, are occasionally met with; but the most singular and interesting fossils in this stratum are several undescribed Crustacea of the Trilobite family.

A few feet above the "White flat", in the northern division, is the "Blue flat" ironstone. The large, mis-shapen nodules of this measure are full of casts of Unios, and vegetable impressions of the order Lycopodiaceæ, well preserved but in great confusion.

A thin seam of clay separates that ironstone from the "yard-coal", upon which reposes the "yellow flat" ironstone, containing a few Unios, and several species of Sigillaria, Calamites, and many genera of Lycopodiaceæ.

The strata, between that bed and the "Top coal," contain organic remains analogous to those of the last three or four beds. The bass above the "Top coal" contains, in Donnington, remains of the Megalichthys, Gyracanthus, and other fishes, with a few Unios. It is only in the north of the coal-field that the ballstone measure is known; the nodules of which are large, and the bed is remarkable for the abundance and beauty of its vegetable reliquiæ. The *Cyclopteris orbicularis*, and several other species of the same genus characterize this deposit. They are always beautifully preserved, every fibre being perfect; and the thin, delicate tissue of the plant is indicated by the sharp and unbroken, though crumpled state of the leaf. This bed is also distinguished by the presence of Lycopodiaceæ, Asterophyllites, and Bechera. I discovered no animal remains in it. It is remarkable that, although the vegetable impressions are so abundant in the ironstone nodules, yet none are found in the shale in which the ironstone is imbedded. This is also the case, in a great degree, with all the fossils of the other ironstone strata.

The thick bed of sandstone which overlies the "ballstone" at Ketley contains only a few vegetable remains, the most common being casts of Calamites.

For several yards above this sandstone, the strata inclose very few fossils, and they are chiefly vegetable.

The "Brick measure ironstone" is as much characterized by the paucity of organic remains, as the other ironstones are by their abundance. I found only three small and imperfect impressions of monocotyledonous plants.

Ten or twelve yards higher is the "Blackstone" measure. This ironstone contains a few casts of Unios and Lycopodiaceæ; and I have found a few specimens of *Orbicula reflexa* in the dark shale of this stratum; and, latterly, in Donnington Wood, some beautifully preserved small Lingulæ, together with remains of fishes.

I am not aware that the strata between the "Blackstone" and "Chance Penneystone" are characterized by any particular fossils. The few which are met with, are imperfect impressions of Ferns, and other plants.

The "Chance Penneystone," which is the highest bed of ironstone in the coal-field, is a deposit of considerable interest. After the great preponderance of vegetables and Unios in the strata, between the Main Penneystone and this, we suddenly arrive at a deposit containing, in great abundance, *Leptæna scabricula*, a fossil found only in the two Penney ironstones in this coal-field. In some places it occurs in great abundance, one or more of these shells having served as a nucleus for almost every nodule of ironstone, to the exclusion of any other fossil which I could discover. This stratum is also characterised by the presence of the Hybodus, *Megalichthys Hibberti*, *Gyracanthus formosus*, and Conulariæ, presenting a remarkable analogy to the Penneystone as existing further southward, and which is 200 feet lower in the series. So great is the resemblance, both in organic remains and lithological character, that it would be almost impossible for any observer to distinguish between the two strata by an examination of the heaps at the pit's mouth; but the Chance Penneystone is not persistent; and I am not aware of its existence further to the south than New Hadley and part of Ketley. As it disappears, the Penneystone becomes richer in organic remains.

To the "Chance Penneystone" succeed several thick strata of sandstone, with a few subordinate

beds of shale, and traces of coal; but they are almost totally destitute of organic remains. In the Lower New Red Sandstone, into which the coal-measures apparently pass, I have met with a few imperfect impressions of soft monocotyledonous plants.

I have not noticed the fresh-water limestone in the foregoing series, as in the northern districts which afforded the principal materials for the previous observations, this calcareous band has not been found.

In it have been discovered the *Microconchus carbonarius*, a species of Cyclas, with the *Cypris inflata**.

Having now enumerated the characteristic organic remains of each bed, it remains to notice only those fossils, the proper place of which in the series is not correctly known. In the collection of Mr. Anstice are two remarkably interesting and singular fossils, called by Dr. Buckland *Curculloides Ansticii* and *Curculloides Prestvicii*. They are the oldest known insects. In the first part of this paper, read before the Society in 1834, I mentioned these fossils, but was unable to state to what genus they belonged. Mr. Mantell says that he has discovered in an ironstone nodule from Coalbrook Dale, the wing of a Neuropterous insect, closely resembling that of the living Corydalis of Carolina†.

The specimen of *Triconocarpum ovatum* figured in the Fossil Flora of Great Britain (Plate CXLII. fig. A.), is also from the Coalbrook coal-field, and is in the collection of Mr. Anstice. It is supposed by Messrs. Lindley and Hutton to have been the fruit of a palm, as recent palms have a three-ribbed thick shell, containing a single seed.

From the length of time since the above fossils were found, the stratum in which they were procured, cannot be ascertained. It was most probably the Ballstone, or the White Flats.

With regard to the habitats, and state of preservation of the fossils, it may be repeated, that the ironstone nodules form the principal depositories both for the animal and vegetable remains, which generally present very sharp and distinct impressions and casts, almost always perfectly free from their original substance. In the shales in which the ironstones are imbedded, I have scarcely found a single vegetable impression. A few fish-scales, shells, and teeth, are sometimes, though rarely, met with in the Penneystone, Top coal, and Blackstone shales; and some of the thin bands of crushed Unios exist in dark bituminous shales. The casts of Lycopodiaceæ and testacea are often filled with crystallized sulphuret of zinc, and sometimes with carbonate of iron, and carbonate of lime. But one of the most common accompaniments of the casts of animal exuviæ, is a white, impalpable powder, in which I have detected silica, alumina, and potash; thus agreeing with the mineral found by M. Guellemin in the mines of Antin, and termed by him *Pholénite*. The shells of the Penneystone measure are almost always ironstone casts; those belonging to the bivalves being generally external, but sometimes internal; and the muscular attachment is frequently marked by a black spot. Some of the larger shells are found in the shale, but the majority are imbedded in the ironstone nodules. In most of the shales and indurated clays in immediate contact with the coal,

* Mr. Murchison's Silurian System, p. 84. † Wonders of Geology, p. 593.

vegetable impressions are common, and they occur, though more rarely, in the body of the same strata. It has been already observed, that, in some rare instances, traces of the original vegetable tissue remain. In one of the black bituminous shales, associated with the yard-coal, are found impressions of Ferns, marked by a thin, bright coating of iron pyrites. The fossil plants in the sandstone strata are almost invariably casts in the matrix, the bark being frequently converted into coal. The principal specimens which retain the internal organization belong to *Stigmaria ficoides*, and were found in the Crawstone; the stem of a large coniferous tree was also found in the flint-coal. The former of these fossils is figured and described in the Fossil Flora (Plate 166. fig. 1 and 2.).

The distribution of the organic remains is extremely irregular in different parts of the coal-field; but the fossils of the lower series, like the strata themselves, are persistent throughout a much greater area than those of the upper. Thus, the *Stigmaria ficoides* and the *Neuroptera gigantea* are found as abundantly at Broseley as at Hadley. The Penneystone measure has been shown to be characterized, at different localities, by the preponderance of peculiar fossils. The sandstone above this measure contains but few plants at Broseley, and they are principally Stigmariæ; whilst at Ketley, Calamites, Sigillariæ, and Lepidodendra, are abundant. The gregarious nature of the Trilobite family is evinced by their congregating within very small limits, for they have been found only in the White Flat, at one pit in Ketley, except a species of Asaphus, which exists in the Penneystone.

The numberless Unios which characterize the centre of the coal-measures at the Horsehays, Malinslee, Ketley, Woombridge, &c., are rarely met with at Broseley and Madeley. The ballstone, with its numerous and beautiful vegetable fossils, is not known much further south than Ketley; and the Chance Penneystone, so full of the *Leptæna scabricula*, is entirely confined to the northern districts of the coal-field; whilst the *Microconchus carbonarius* and *Cypris inflata* have not been detected to the north of the Severn.

NEW RED SANDSTONE.

(Plates XXXV. and XXXVI., figs. 1 to 16.)

This important and extensive formation wraps around the two longer sides of the acute-angled triangle in which the foregoing series are developed; its disjointed edges abutting, as already mentioned, against those of the several older deposits.

Mr. Murchison* has shown, that the new red system, in its range through Cheshire, Shropshire, Staffordshire, and Worcestershire, consists of the fol-

* Proceedings Geol. Soc., Vol. II., p. 563, Feb. 1835. Geol. Trans., *ante* p. 31.

lowing divisions; only the three lower of which occur in the immediate neighbourhood of Coalbrook Dale.

	Foreign Appellations.
1. Red and Green Marls.....	*Keuper* and *Marnes irisées.*
2. Sandstones and Conglomerates.....	*Bunter Sandstein* and *Grès bigarré.*
3. Calcareous conglomerates.....	*Zechstein* and *Calcaire magnésien.*
4. Lower Red Sandstone.....	*Rothe Todte Liegende.*

At Rowton Farm, near Caughley, are exhibited alternating strata of gray, mottled, liver-coloured shales and marls, of a dark red tenacious clay, and of coarse dark-brick red, and light gray, micaceous sandstones, sometimes finely conglomeratic, belonging to the lower red sandstone (No. 4.). Owing to the numerous faults which surround and cut off the coal-measures, the relation of that formation to the new red sandstone cannot be satisfactorily ascertained. The dip of the two formations generally appears to be in the same direction; and, in the south of the field, the lithological characters of the upper strata of the coal-measures so closely resemble those of some of the lower beds of the new red sandstone, that the latter might, in many cases, be mistaken for coal-measures. Imperfect impressions of the leaves of soft, monocotyledonous plants occur, though rarely, in some of the sandstone beds. The characters, here exhibited by this portion of the red sandstone, offer the greatest analogies to those of the lowest beds of the deposit in the north of England, as described by Professor Sedgwick, in his able memoir on the Magnesian Limestone*.

Upon this lowest division repose thick strata of characteristic brick-red and yellowish sandstones, with a few subordinate beds of calcareous conglomerate (No. 3.), composed of angular and slightly rounded fragments of limestone, which contain characteristic fossils of the mountain limestone, and are imbedded in a red, arenaceous cement. These equivalents of the dolomitic conglomerate are rarely visible.

In Apley Park, and in a field between the Windmill and Homer Farms, they were formerly quarried; and it is probable that a thin, irregular zone of them may range parallel to the eastern boundary of the coal-measures; but, owing to the abundance of limestone at Lilleshall and Steeraways, the conglomerate is not sought after. At Homer Farm, the sandstones of this division are brought very near to the coal-measures, and along the line of the boundary fault, they appear, in many places, to be in immediate contact with the carboniferous and trap rocks.

To this division succeeds a considerable thickness of bright red sandstones, mottled marls, and coarse conglomerates (No. 2.), which are interesting,

* Geological Transactions, 2nd Series, Vol. III., p. 37, *et seq.*

as they afford a clue to the strata, the detritus of which has served to form the deposit. In a quarry about half a mile W.N.W. of Shiffnall, I found rolled fragments of the following rocks imbedded in a red, finely brecciated mass of the same materials.

White and red quartz;

Igneous rocks, similar to those constituting the Wrekin and Lilleshall hills;

Carboniferous limestone, resembling that of the Lilleshall Red limestone; and

Sandstone and ironstone, apparently from the coal-measures.

To these conglomerates succeeds a thick series of marls and sandstones, which belong to the uppermost divisions, but which do not come within the range of the district described in the paper.

The lines of joints cannot be easily recognized in this rock. A good case, however, occurs at Houghton, near Shiffnall, where several beds of the coarse conglomerate, above mentioned, are traversed by well-defined joints, ranging E.N.E.; and it presents great additional interest, from the marked illustration which it affords of the powerful action of the agent which produced the joints. The majority of the imbedded pebbles, some of which are six to ten inches in diameter, belong to rocks of great hardness, sometimes laminated, sometimes not, the matrix being the most friable portion of the stratum; the joints, nevertheless, traverse the beds perpendicularly, dividing them as with a knife, and pass through all the imbedded pebbles within their range. In any other fracture the strata present a studded surface.*

ROCKS OF IGNEOUS ORIGIN.

(Plates XXXV. and XXXVI., figs. 1, 2, 5, 6, 7, 9, 13 and 15.)

In so disturbed a district as Coalbrook Dale, igneous rocks may be expected to abound. It has been stated that the coal measures and older deposits flank a great igneous axis, the effects of which are described among the "lines of disturbance." The elevated ridge of the Wrekin and Ercal is a portion of this axis, ranging S.W. and N.E. The nucleus of the Wrekin consists of a very hard, splintery, reddish gray hornstone, and that of the Ercal of a felspar porphyry or eurite, composed of light flesh-coloured compact felspar, inclosing a few small grains of colourless quartz and crystals of red common felspar. These rocks do not exhibit any indications of columnar structure. They are surrounded by a

* At Admaston, a saline spring rises in the new red sandstone, near a mass of trap; and the brine spring at Kinley-wich is similarly situated. Dr. Townson, describing the latter spring, says it yields 4000 to 5000 gallons in the twenty-four hours. It is an impure brine, but was formerly used. It flows out of reddish sandstone, resting upon a reddish chert like that of the Wrekin. See Townson's Tracts, p. 179.

fine grained, hard, dark, dull-looking porphyritic greenstone, in some places slightly amygdaloidal, and traversed by parallel divisional planes. It has the appearance of having been tilted at angles of 50 or 60 degrees, by the interior nuclei, an arrangement which suggests the subsequent protrusion of the eurite; and from the manner in which the quartzose grits are connected with the greenstone, I am induced to consider the latter as one of those numerous igneous rocks, which are interstratified with the lower Silurian formations.

To the east of this main axis and parallel to it is a small ridge of dark, very compact greenstone (see Map, Plate XXXVI.). Another extensive outcrop of igneous rocks ranges S.S.W. and N.N.E. from the "Spout" to Steeraways. It consists of a fine-grained greenstone, generally syenitic and sometimes amygdaloidal, with siliceous and ferruginous concretions. This ridge has evidently been protruded, as it tilts the limestone eastward at a high angle. There generally occurs*, between the carboniferous series and the greenstone, a dark, hard basalt, passing into wacké, sometimes of a dirty yellow colour and a soft earthy texture; more frequently, however, of a dark liver-red, occasionally fragmentary and hard, with a lustrous surface, but oftener friable and clayey; in some places it is amygdaloidal, with concretions of phrenite and oxide of iron. This superposition is observable at the Hatch (see Pl. XXXVII., fig. 6.), and around Little Wenlock, where the dip of the trap conforms to that of the carboniferous limestone, which it immediately underlies. In the ravine at the northern extremity of the Dale, a somewhat analogous deposit is found, surrounded by the lower coal-measures; and incumbent upon a very compact basalt, divided into large irregular spheroids. A similar basalt appears at nearly the same level, a short distance west of the Horsehays, near the centre of the field. Proceeding northward, the coal-measures repose in places near Ketley upon soft earthy trap and common and amygdaloidal trap. No outcrop is visible; but this superposition was discovered, some years since, in driving a water-level from Ketley to the Old Park; as it passed for the greater part of the distance through an extremely hard crystalline basalt†. The level is abandoned, but it may be traced by the mounds of trap collected at the different air-shafts. I could not learn that the coal-measures were altered by the proximity of these igneous products; and at the old pits at Little Wenlock, where the two rocks are brought into abrupt juxtaposition by a large fault (No. 23 of Map), intelligent colliers have assured me, that the coal shales and sandstone were

* The soil formed by the disintegration of this deposit is extremely fertile.

† Owing to the extreme hardness of this rock, Mr. Reynolds procured workmen from Derbyshire, whence it is known as the Derbyshire level. As far as I could ascertain, the length of this tunnel was about $1\frac{1}{2}$ miles, a great part of which passed through basalt and trap.

worked up to their point of contact with the "black rock" or basalt, without presenting the slightest alteration*; neither is the regularity of the plane of dislocation at all disturbed in this part of its course. (See Section 7.) I am, therefore, inclined to consider that the basalt and trap were ejected previously to deposition of the carboniferous series; and from the irregularity of its surface and the thinness of the carboniferous limestone, that the latter formation merely decreased the first inequalities, and that the coal-measures of this portion of the field were deposited on an irregular bed, consisting either of limestone or of igneous rocks. We have, however, elsewhere evidence that the coal-measures have been affected by other igneous rocks of more recent date. Thus along the boundary fault, although no trap crops out, it has been met with at various points below the surface. I have been informed, that in the boundary fault near Donnington furnaces and near New Hadley, a rock similar to the nucleus of the Wrekin was found in making a shaft; and at both these localities the coal near this fault is altered into a sooty substance. At the Madeley fault, near the Hay, the coal was in the same state, and the ironstone was red as if calcined. In these instances the deteriorated quality of the coal and ironstone, and the difficulty of excavating the hardened rocks prevented the workmen from proceeding in a direction which might have exposed more fully the cause of these changes. (See Sections 3, 4, 9.)

Other small bosses of greenstone and basalt appear on the side of the canal near the Horsehays, at Coalmoor Farm, Harris Coppice (Sec. 7, 8.), Saplin Farm, &c.; the two first protruding into the coal-measures, the last into the Wenlock shale; and that at Harris Coppice separating the two formations. At the apex of the coal-field is the mass of igneous rocks forming Lilleshall Hill, the last visible effort, in this district, of those disturbing agents to which we probably owe the outcrop of the field. This hill consists of a nucleus of light greenish claystone, passing into a reddish gray hornstone, surrounded by a zone of greenstone porphyry, and therefore resembles in composition the Wrekin.

The igneous rocks are not, however, confined to the angular area of the carboniferous and Silurian series, for they protrude also through the new red sandstone which surrounds it. At Kinley Wich, a boss of hornstone similar to that forming the nucleus of the Wrekin projects through the sandstone.

The most important outcrop of igneous rocks in the new red sandstone occurs at Wrockadine, Seaton, Burcot, Rushton, and in Southward. It forms a slightly hilly district, rising to the height of about 350 feet above the level

* I had not an opportunity of inspecting this phenomenon underground, as the works have been abandoned for some years.

of the sea, and it ranges parallel with the Wrekin. Like that mountain it consists of greenstone, felspar porphyry, and hornstone. I cannot state accurately its effects upon the adjacent rocks, but it appears to have brought to day, on its eastern flank, patches of the coal-measures, in the same manner as at Longwood.

The minerals found in these igneous rocks are confined to small reddish crystals of felspar in the eurite of Ercal Hill; small crystals of quartz in the cavities and crevices of the greenstones, to a few veins of carbonate of lime, crystals of augite, grains of olivine and traces of iron pyrites in some of the basalts and greenstones. Phrenite and oxide of iron occur in the amygdaloids.

LINES OF DISTURBANCE.

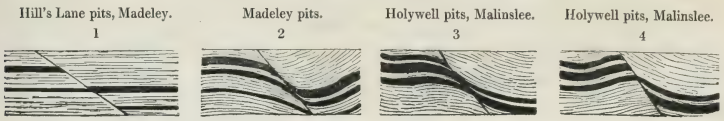
Few coal-fields have probably been more shattered than that of Coalbrook Dale; and its numerous as well as extensive faults forcibly illustrate the energy of the disturbing agent. Deposits, several thousand feet thick, and occupying an area of many miles, have been shivered into fragments, and the broken remnants have been placed in the most discordant positions, and very often at levels differing from each other, many hundred feet.

In selecting the faults described in the following pages, I have chosen only such as illustrate the leading effects of the protrusion of the carboniferous and older rocks through the new red sandstone, and which exemplify the magnitude and direction of the disturbing power. I have prepared a tabular list of the effects of these major faults, together with those of numerous minor ones, which it would be tedious to notice in detail (See Appendix D.)

The collier can rarely proceed many hundred yards in any direction without encountering a fault of some magnitude; whilst slips or dislocations of less importance frequently occur every three or four yards. Although the continuity of the strata is thus interrupted, and some inconvenience is produced; yet the faults are accompanied, as many writers have stated in describing other coal-fields, by advantages which far outweigh the evils arising from their temporary obstructions. Various disjointed beds of coal and ironstone are thus brought on a level, though, if their horizontal range had not been disturbed, they would be separated vertically many yards. An instance occurs at Broseley of four beds of coal and one of ironstone, each separated by several feet of shale and sandstone, being rendered accessible upon the same adit by means of successive dislocations. Again, were it not for these fissures, a great portion of the deeper part of the coal-field would be unworkable, on account of the water draining from the higher strata. Through their agency also, the

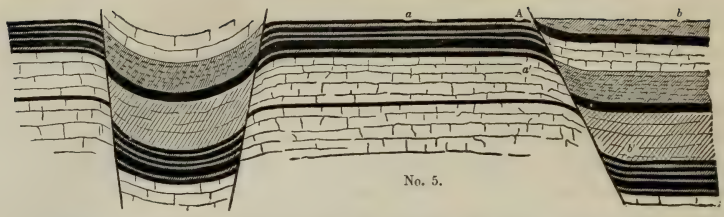
deeper seated coals and ironstones have been discovered and rendered available.

Previously to describing the range of the faults, I will briefly explain their nature and characters. The edges of the disjointed strata are generally in contact, or are separated merely by a layer, a few inches thick, of clay, frequently nearly white. The fractured surface is usually striated or ribbed vertically; and, where this layer of clay is wanting, the coal, as well as the bituminous shale, presents highly polished surfaces. In some parts of the field, the colliers have "black and white slips" or very small faults, which cross at various angles. The black, which are almost always parallel to the main face of the coal, present smooth and polished surfaces, whilst the white slips contain a thin layer of clay. To this point I shall again refer. The inclination of the faults appears to obey no general law, varying in the range of the same fault from 45° to 90°. For instance, Mr. Jones of New Hadley found that the horizontal distances in the uppermost and lowermost beds of coal between the shaft of a pit near Potter's Bank and the line of the Ketley fault, were equal, and consequently that the fault was perpendicular. This fault is, in other places, considerably inclined. When the sides of the fissure are perpendicular, they are commonly separated several yards, sometimes as much as forty or fifty, the interval being filled with broken debris of the strata. Generally, however, the sides of the fissure, instead of having been forced asunder, have been strongly compressed. In most cases the edges of the strata are turned upwards on the side of the lower level, and downwards on that of the higher, or in the expressive language of the colliers, "the measures rise to a rise, and dip to a swamp*." There are a few rare instances, however, of the reverse. The following diagrams exhibit examples of small faults or slips in the lower coals. (For examples on a larger scale, see Sections, Plate XXXVI.)



A good instance of lateral pressure is exhibited in the following wood-cut, taken from a Section in the Holywell pits, Malinslee.

* The phraseology of the colliers with respect to faults is extremely convenient. The whole district situated upon the higher side of a fault A is said to be on the rise of fault A; and the whole of the district on the lower side is said to be "in the swamp." Thus, in fig. 5, *a* is on the rise of fault A, or simply "on fault A"; *b* is in the swamp of ditto: stratum *a'* dips to the swamp of fault A; stratum *b'* rises to the rise of ditto.

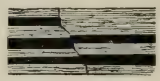


Generally, however, the strata on the sides of the small slips are not much contorted. The above instances (2, 3, and 4,) are more commonly applicable to the larger faults, as in 5. The following section of the "best coal" along a level at the Meadow pits, Madeley, shows the prevailing character of the small disturbances.

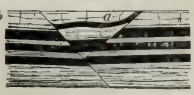
6.

Sometimes, owing apparently to the greater hardness of certain strata, the line of fracture assumes a step-like form, as in the annexed diagram 7, taken in the lower coal level at Priorslee. Where two slips have met, singular effects have been occasionally produced, as in diagrams 8 and 9 taken in the Hill's Lane pits, Madeley. No. 8 is situated in the best and clod coals, and No. 9 in the little flint coal, and is on a larger scale than the other diagrams.

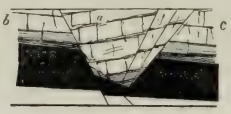
7.



8.



9.



10.

These disturbances are difficult to account for: *a*, *a'* appear to be masses subsided or fallen into a wedge-shaped fissure, enlarged probably at the moment of disturbance by the increased separation of *b* and *c*, so that *a'* would fall into the cavity and crush down the seam of coal as in No. 9.

The intersection of two faults occasionally presents the phenomena in diagram (10).

A small fault or slip usually commences by a simple fracture, accompanied by a slight difference of level between the two dislocated sides; but the difference rapidly increases, until the smaller fault joins a larger fault (see Map, Pl. XXXV., also *a*, Diagram 11, page 455). Thus the Arleston fault, which commences between New Hadley and Ketley as a simple fracture, at-

tains, in the course of its range towards Arleston, and at the distance of about a mile from its first appearance, a vertical change of level of about 100 feet. Numerous other instances might be adduced; sometimes, however, a fault will thin off at each extremity in a simple fracture, as in fault 19, Pl. XXXV., which ranges about half a mile, and produces a difference of level amounting to 30 feet in the centre of its course.

In the Old Park, (Map, Plate XXXV. fault 33.) is a series of four of such faults, in parallel and consecutive planes, one fault commencing at a point in one plane corresponding to that where another fault ended in the adjoining plane. The maximum effect of one of these faults is about 24 feet, and the range of the whole amounts to nearly three quarters of a mile (see Map). At Wrockadine Wood, two faults cross at an angle of 55°, and the disturbance of both amounts, at a few hundred feet from this spot, to 25 feet; but at the point of intersection the faults diminish to mere fractures, which do not affect the level of the strata.

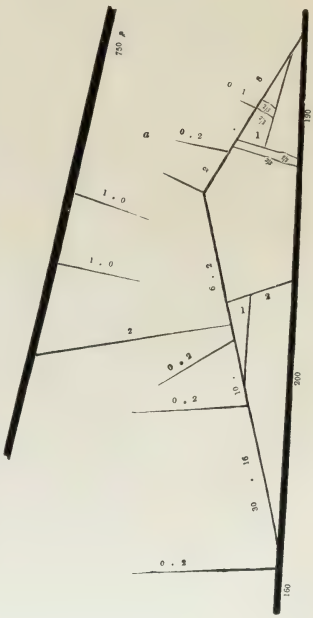
Some of the small slips extend but a few yards and produce only 1, 2, or 3 feet of vertical disturbance. These minor dislocations are so numerous that it would be almost impossible to lay them down. In the map, therefore, I have represented only those which have not less than 20 feet of vertical change of level.

The annexed plan of a small district between the Boundary and the Ketley faults exhibits, however, the ramifications of the whole system of fractures. It is a solitary instance of a plan of all the minor faults carefully and minutely laid down by a ground-bailiff, Mr. Jones, of New Hadley. The numbers refer to yards, denoting the amount of disturbance, and are placed on the side of the highest level.

Thus 1 . 0 or 0 . 2 denote that the fault at its point of junction with a larger one produces a difference of level of one or two yards, gradually decreasing as it recedes from that point to zero.

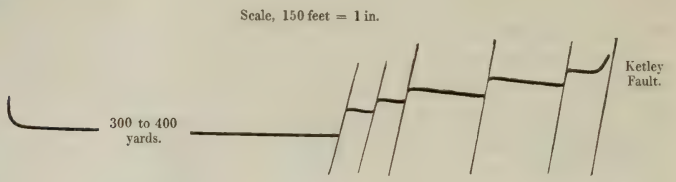
All the large and main faults also vary greatly in the course of short distances.

11.



Near Woombridge church the

Ketley fault produces a change of level between 500 and 600 feet; but at New Dawley, distant two miles, of only 40 or 50 feet. The Lightmoor fault at Snedshill produces a change of level of 300 feet; at the Dark Lane and Malinslee, of nearly 700 feet; at New Dawley, of 350 feet; at Dawley Green, of 400 or 450 feet; and at Great Dawley, of 500 feet; but at Lightmoor it diminishes to 300 feet. This variation arises partly from the junction of other faults, but is principally owing to a slight difference in the angle of dip of the disjointed portions of the coal-field. I have mentioned that the edges of the disjointed strata are generally much bent; the bend being frequently flanked by a series of small faults. Thus, in the following diagram of the dislocations, on approaching the Ketley fault, near Donnington Wood furnaces, a series of minor faults is represented flanking the principal or Ketley fault.



The same effects are exhibited in several parts of the Lightmoor fault, and likewise precede the Madeley fault near the Hay House. They were noticed also on approaching the line of the Great East fault at Southall. The rapidity of the dip stopped the miners before reaching the main fault.

The phenomenon of a principal fault flanked by numerous smaller ones, is termed by the colliers "the splitting of a fault." Thus the Ketley fault is said to split upon approaching the boundary fault near Donnington Wood furnaces. (See Map). Whether in this and other cases the side or branch faults result from a temporary and local division of the larger fault, whether they proceed in gradually diminishing magnitude from the large faults, or whether they form a series of small parallel and independent faults, I have no positive data to prove. I am however inclined to adopt the two latter hypotheses.

It is rather remarkable, that although the district is so much disturbed, and bosses of trap protrude in many places through the sedimentary strata, yet there is only one instance of an apparently continuous trap dyke. This occurs in the case of the Boundary fault, along which are indications of the proximity of trap, a mass having been met with near Woombridge, and the coal along great part of the line from Ketley to Donnington being converted into smut. This change of coal into a sooty substance has been noticed also

at Madeley, near the Hay House. For an account of the effect of the trap rocks, see *ante*, p. 449, *et seq.*

The faults cannot be traced by any modification of the surface; as they pursue their course indefinitely over hill and through dale; and those towering irregularities, due immediately to the convulsions, powerful effects of which are still attested by the fractured and shattered strata, have been leveled and swept away, leaving scarcely a trace of their presence.

It must, however, be observed, that, although the masses of strata do not retain their original superficial inequalities, as effected by the dislocations, yet these disturbances have materially aided in modifying the outline of the country, by bringing to the surface, rocks of different degrees of hardness, which having yielded very variously to powerful denudations, great diversity of hill and dale has been produced.

The "Symon fault" not being the result of fracture, is treated of under the head of lithological characters. (See p. 432.)

Having taken considerable pains to trace the faults of this district, I am able to describe them in some detail*. To avoid minutiæ, however, I have arranged them, as far as possible, in a tabular form; and all dislocations of less than 20 feet of difference of level are, with few exceptions, omitted, as well as in the sections and plans. (See Appendix D.)

The two principal faults, called the Lilleshall and the Great East, diverge at an angle of about 20°, a little south of Newport, and bring up a wedge of the Silurian and carboniferous rocks into horizontal juxtaposition with the fractured edge of the new red sandstone. After ranging southward nearly four miles, a central axis of disturbance intersects longitudinally the included coal-measures, and divides them into three distinct systems, each bounded by prolonged and nearly parallel lines of fissure, ranging between the limits of N.E. and S.W. and N.N.E. and S.S.W., and called the Boundary, Ketley, Lightmoor, and Great East faults. The two exterior systems constitute at first deep troughs. This trisection of the coal-field forms a very marked feature in the Woombridge and Ketley districts; but as we proceed southward the depth of the eastern system of beds, compared to that of the central, considerably increases, and in the same district the western becomes nearly as shallow as the central. Thus the coal-measures in the western and

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* The following observations are much more ample than those contained in the memoir read February 1834, which presented a short sketch of the principal faults. I have now added further details respecting their range, connection and effects. In detecting these disturbances I received great and valuable information from the miners; but, owing to their experience being confined to small areas, they are, with few exceptions, unable to trace the range of any fault. Although, therefore, I have taken every care in dovetailing these several fragments, slight inaccuracies in the exact course and termination of some of the minor faults may exist. Where considerable doubts have been entertained, I have omitted the information altogether. The courses and magnitudes of all the larger and more important disturbances are, I trust, laid down correctly.

central divisions gradually thin off, until, in the parallel of Little Wenlock, they entirely crop out, after a range of 9 miles. Within the same range the eastern division increases in breadth and importance, but its continuity is for a short distance completely broken by the limestone fault, which crosses it diagonally from S.W. to N.E., and tilts up this division of the coal-measures to the westward. (See Map, and Section 8.)

After crossing the Severn the same eastern division widens considerably, but it is much broken and elevated by a series of transverse fissures, some of which are parallel to the limestone fault, but others are at right angles to it. In consequence of these dislocations the coal-measures gradually and irregularly crop out, and the Silurian rocks are brought to the surface.

The above systems of longitudinal disturbances are affected by numerous small transverse faults, which, proceeding from one of the principal dislocations, sometimes extend across to another, but more often gradually diminish in their range, and disappear. These transverse fractures diverge from the main longitudinal ones at all angles; but the larger commonly at 90°. In the deeply seated strata of the northern portions of the coal-field, their number is comparatively small; but in the parallel of the igneous axis of the Wrekin they are extremely numerous. At Langley, Lightmoor, and Madeley, they are of rare occurrence; and again, as we proceed south over the Severn to the edge of the coal-field, they become very numerous.

Returning to the western system we find it gradually rising towards, and ultimately, obliquely intercepted and thrown out by, the mineral axes of the Wrekin and Steeraways, which we will now consider. The Wrekin is a long knife-edged mountain, ranging from S.W. to N.E., and rising to a height of 1320 feet above the level of the sea. It is formed by a central ridge of igneous rocks, flanked by the lower Silurian deposits. Its length, including the Ercal and Primrose hills, is three miles, and its breadth is about two-fifths of a mile. Towering high above the disturbed district, of which it forms the main axis, and still higher above the surrounding and extensive tract of new red sandstone, it constitutes a fine isolated and conspicuous object.

Parallel to the major axis, and on the north-west flank of the Wrekin, are evidences of a very large fault, by which the disjointed edges of the new red sandstone are brought into contact with those of the lower Silurian rocks. The latter are seen to dip rapidly to the foot of the Wrekin and Ercal hills; and although we meet with no section exhibiting their juxtaposition with the new red sandstone, still, from the circumstance of having found this deposit in a well on the farm close to the foot of the Wrekin, dipping but slightly towards the north, and again to the north-east, near Eaton Constantine; and, from the specimens dug out at the foot of the Wrekin, indicating that the beds there do not belong to the lowest members of the new red sandstone, and likewise from the formation ranging in a nearly straight line parallel to the Wrekin, and not extending into the transverse slopes and glens, I think we may fairly infer the existence of a very considerable dislocation west of the Wrekin, and into which the Boundary fault merges somewhere at the northern extremity of that igneous axis. Again, as we know the coal-field to be fractured, and its level, with regard to the new red sandstone, greatly altered, both on its eastern side and on its north-western, from Lilleshall to Steeraways, at which point commence the igneous axes of the Steeraways and Wrekin; it follows, that as the coal strata are disturbed relatively to the new red sandstone in the parallel of Woombridge, so, in the parallel of the Horsehays, to the east of the Wrekin, where we trace the prolongation of the same disturbance in the coal-measures, the relation of the carboniferous series to the New Red Sandstone must continue the same; and that, though separated by the Steeraways and Wrekin hills, the terminating planes of both those formations must be fractures.

Nearly parallel to this axis of eruption, and at the distance of $3\frac{1}{2}$ miles to the S.E., ranges

another important but minor line of disturbance. In its course through the coal-measures, where its nature can be advantageously studied in the extensive works at Lightmoor and Madeley, it is known as the "Limestone fault," from the circumstance of its axis being composed of Wenlock limestone and shale.

This disturbance forms an anticlinal line; and from the phenomena exhibited in its passage through the coal-measures, it appears that a narrow, central ridge of the subjacent deposits is protruded between the fractured edges of the carboniferous strata, throwing them off, in nearly vertical dips, but in opposite directions, and producing a change of level, higher, on the N.W. side, by 200 or 300 feet. This disturbance, however, merely affects the position of the strata in its immediate proximity; for, at the distance of less than a quarter of a mile on each side, the usual slight dip to the eastward, is unaltered by it, even at the depth of 700 feet. (See Plate XXXVI., sections 15 and 16.) The inclination of the included Silurian strata cannot be well ascertained, as they are much broken. The outcropping edges of the Wenlock limestone, which flank the southern side of this disturbance constituting Lincoln Hill, and Benthall and Wenlock Edges, dip rapidly towards the S.E., and have escaped the denudation which has removed the underlying shale from the centre and N.W. flank of the axis; wherefore the opposite dips, although very visible in the coal-measures, are not well marked, where the axis traverses the Wenlock shale.

At Benthall Edge, the centre and the north-western flank of the anticlinal ridge have, by the denudation of the Wenlock shale, been worn into a deep valley. At Tickwood Hill the strata are much broken, and have a quâquâversal dip. The southern prolongation of this anticlinal fault probably produced the well-marked ridge of Wenlock Edge.

Northward, the Limestone fault is not traced beyond Windmill Hill, but it continues its north-easterly range towards Shiffnall.

Parallel to, and south-east of this second axis, are several smaller disturbances, producing slight anticlinal lines, which present a central and broken nucleus, a few yards broad, bounded by two parallel fissures, from which the flanking and disjointed strata rapidly dip, and exhibit, as in the preceding instances, proofs of considerable lateral pressure. The first of these small anticlinal lines is about $2\frac{1}{2}$ miles to the S.E. of the Limestone fault, and ranges, by the Upper Ridding, across the Broseley and Bridgenorth road, at the Dean, to Willey and Shirlot. Another anticlinal line exists one mile S.E. of the last, traversing the Ludlow rocks and the lower coal-measures, and is exposed in the brook below Caughley, and near Linley Hall.

In the preceding cases the disturbing power appears to have acted in a direction nearly S.W. and N.E.; but at the northern apex of the coal-field is a short, eruptive axis of trap, partially flanked by Silurian and carboniferous strata, ranging nearly N. by E., and S. by W., and constituting Lilleshall Hill, which rises to the height of 433 feet above the level of the sea. It is bounded on the N.W. side by a large fault, which brings the new red sandstone against the trap and the Silurian rocks and carboniferous limestone. In its prolongation towards the southwest, it joins the Boundary fault, whilst towards the north-east it apparently intercepts, at an acute angle, the Great East fault at Church Aston; and is most probably continued with it into the new red sandstone.

The abrupt termination of this axis on the south is remarkable. It should intersect the Donnington field, but we there find the strata in the plane of the axis, and distant from Lilleshall only $1\frac{1}{2}$ mile, entirely unaffected by it, and nearly horizontal, with only a few transverse faults; while as we proceed southward, it again shows itself in the elevation of the central division of the coal-measures of which we have already spoken. Its subsidence northward is equally rapid.

Notwithstanding all the dislocations, disturbances, and changes of level, which we have enumerated above, the coal-measures and the other formations are not much contorted; neither is the angle of dip materially affected. Were it not for the actual exposure of a fault by means of sections, or more generally in the pits, its existence could rarely be inferred from the relative dips of the disjointed strata. I now allude to a case where a repetition of similar lithological characters renders a positive recognition of the majority of the strata impossible. For example: from the dip at Bullock's Leasows and Randley, an observer might easily suppose a perfect continuity of strata between those two places—the planes having a similar inclination, and in no wise indicating the important intervening fractures. (See Section 6.) From the dip of the strata at Amies and Caughley, they might be supposed to range likewise uninterruptedly between those two places; whereas a disjointed section of New Red Sandstone separates them.

We might also imagine, from the dip of the carboniferous series at Steeraways, that a considerable fault ranged between that highly-inclined outcrop and the nearly horizontal strata half a mile to the east, but only small slips have been noticed. (See Section 5.) So on both sides of all the large faults, the disjointed strata preserve a near parallelism of dip.

Thus, notwithstanding all the dislocations, the deposits maintain a general dip eastward, dependent upon the main line of disturbance or the protrusion of the igneous axis of the Wrekin. (See Sections 3, 4, 5, 6, 7, &c.*).

Diluvium, or Drift.

The district bears evidence of a powerful aqueous action on its surface, a large portion of it being covered with thick accumulations of gravel and sand. These deposits are frequently separable into two divisions: the lower consisting of a fine red sand, associated with beds of angular and rounded pebbles, derived from the adjacent rocks; and the other of gravel, composed also of rolled pebbles of the neighbouring formations, with a few small boulders and pebbles of granite and older rocks, imbedded in a coarse, reddish sand, frequently much mixed with clay. Where the sand is wanting, the separation of the two gravels is almost impracticable.

The sand occurs in only limited patches, though of considerable thickness, both in the valleys and on moderate elevations, but more especially on the sides of hills. Thin, distant seams of marl and clay show the irregular and cur-

* From the phenomena detailed in the preceding pages, it appears, that the coal-field is but a fractured portion of a larger deposit; the remainder of which must, therefore, exist below the surrounding new red sandstone. From the large faults which we know to traverse the coal strata, and many of which are doubtlessly prolonged through the new red sandstone, the former may, in some places, be brought within a moderate depth from the surface. Still, from the proved irregular persistence of the coal and ironstone strata, it would require great caution in inferring the existence of those beds below any given portion of the new red sandstone, except in the places adjacent to the line of fault, where the coal-measures are well-developed and productive at their abutment.

vilinear deposition of the mass. In the sand are frequently found angular fragments of coal varying in size from a marble to blocks 5 or 6 feet in diameter; and extensive accumulations of local gravel, of very variable thickness, are generally exhibited in its lower part. I discovered no organic remains in this deposit.

On the hilly district south of the Severn the sand is not abundant, though traces of it occur in Benthall and Posenal parishes; but it has accumulated in beds of considerable thickness in the valley of the Severn from Coalbrook Dale, through Buildwas and Cressage, and thence westward, covering almost everywhere the Wenlock shale and Caradoc rocks. In some places, it forms small hillocks, as near Buildwas Abbey; at others, as at Strethill and Shineton, it flanks, to the depth of several yards, the sides of the hills bordering the valley. On the platform of the coal-measures it is again less abundant, and only in patches, as at Lightmoor, where it is dug for the use of the iron furnaces. It may be thence traced occasionally on the flanks of the hills and in the valleys through Dawley and the Horsehays, increasing in importance as it ranges northward, and extending over great part of New Lawley, New Dale, and Ketley. In the latter place it much resembles the sands of the new red sandstone, and is extensively excavated, for the moulds at the iron furnaces, by the side of the high road immediately west of the Ketley works. It also covers the surface rocks around Wellington, Hadley, and Woombridge; likewise the low ground of Donnington, and the north of the coal-field. Westward of the Wrekin it appears very generally in the valley ranging parallel to that mountain.

The overlying deposit of gravel is of more general occurrence. It consists of rolled pebbles of the adjoining Silurian and trap rocks, limestone, red sandstone, the shales, sandstone, &c. of the coal-measures; also of a few small boulders of granite, and schistose rocks. Fossils from the Wenlock shale and limestone are extremely abundant in it at Madeley and on the south of the Severn. In some parts of the valley on the eastern flank of the Wrekin, this drift is imbedded in a tough, brownish clay derived apparently from the degradation of the trap and other igneous rocks of the neighbourhood.

Mr. Thursfield of Broseley discovered in the Willey gravel-pits a very singular fossil. It was much water-worn, but displayed a chambered tube inclosed in a sheath, to which it was attached by connecting septa. From its mineralogical character, it had been probably derived from the Wenlock limestone or shale. It possesses considerable similarity to the Orthoceratites from the shores of Lake Huron, figured in one of the plates which accompanies Dr. Bigsby's paper, in the Geological Transactions, 2nd Series, Vol. I.

Beds of coarse gravel and sand, formed apparently by the junction of the two foregoing divisions, abound in the valleys and on many of the hills from Bridgenorth to Lilleshall, accumulating in great thickness in some valleys, as in Willey Park, in Lightmoor Old Park, New Lawley, and Woombridge. Although it ranges over several hills, attaining, as does the sand, a height of 700 feet above the level of the sea, still the summit of many of the hills and the surface of a few valleys are free from it. The thickest deposits are in the valleys running from the lowlands westward of the coal-field, as Muxton, Oaken Gates, Ketley, New Dale, New Lawley, and Buildwas. Eastward of the coal-field, it abounds over the new red sandstone, especially through the parishes of Sutton and Brockton. The rapid variation in the thickness of this deposit is everywhere remarkable. At Hills Lane, where the ground, although high, is level, the thickness in one place is more than 90 feet, whilst 100 yards distant it is only 7 feet. It is frequently found to be 50 to 60 feet thick, as at Willey, Lightmoor Park, in places near New Lawley furnace, Ketley, Woombridge, New Hadley, and Donnington. A good instance occurs in the valley extending from New Hadley to the Oaken Gates. Near Woombridge church the Ketley fault throws up, to the eastward, the lower series of the coal-measures, the strata cropping out successively on the sides of the hills, leaving the lower coal-beds in the valley; but owing to the deep and extensive denudation in this valley, the coals are frequently removed, and at other places are immediately overlied by the gravel, and cannot in consequence be worked. The denuding action of the water has here worn a deep and precipitous channel, on the north side of which the truncated coal-measures being cut off almost vertically, the gravel filling the channel acquires, in a few yards, a thickness of above 100 feet.

It thus appears that the drift has accumulated principally in valleys, hollows, and narrow channels, but that it spreads occasionally, in decreased thickness, over the high grounds*, materially modifying or leveling the more considerable irregularities of surface.

Marine shells of recent species are occasionally found in the upper gravel. Amongst them are specimens of an Ostrea and of a spiral univalve much broken, but apparently of the genus Turritella†.

* The frequent occurrence of this drift interferes greatly with the examination of the surface rocks, preventing, in the more level districts, any natural sections from being exhibited.

† In Mr. Murchison's account of this drift in its extension over Salop, Cheshire, Worcestershire, &c., the *Buccinum reticulatum*, *Dentalium entalis*, *Littorina littorea*, *Tellina solidula*, *Cardium tuberculatum*, *Cyprina Islandica*, *Turritella ungulina*, with fragments of Venus, Astarte, and Donax, are stated to have been found in this gravel; and amongst the localities quoted is one near Wellington. See Silurian System, p. 533.

Conclusion.

In the foregoing pages I have confined my observations solely to the geological description of the coal-field and the accompanying formations, without reference to any hypothesis deducible from the details. I now propose briefly to restate those facts, and afterwards to draw such conclusions as they may appear to warrant.

I intend, in the first place, to investigate the mode of deposition, and to endeavour to ascertain the age of the coal formation; secondly, to review the nature and effects of those disturbances which have so powerfully affected the several formations; and, thirdly, to examine the nature of the agents, which have since acted upon and modified the surface.

The first point involves the disputed question, whether the coal was formed from vegetables which grew upon the spot now occupied by it, or from vegetables transported from a distance.

It has been shown that each stratum of ironstone and several of the beds of shale and sandstone are characterised by peculiar organic remains; and in some cases of a most decided nature. Thus the "white flats" are distinguished by several new and peculiar species of Trilobites, and the Penneystone measures by *Orthocera, Spirifers,* and *Nautili.* From observations upon those beds which admit of ready and extensive examination, it has been ascertained, that the northern division of the coal-measures can be divided into deposits alternately characterised by marine with some fluviatile and terrestrial remains, or by solely freshwater and land exuviæ; and it is not improbable that a further inspection of the less exposed strata will enable future observers to establish a greater number. At present I know of five decided alternations, and of two which are doubtful, as only fishes have been found in them.

Terrestrial detritus	Such at present appears to be the character of the thick and unproductive strata lying above the Chance Penneystone.
1. *Marine* and Fluviatile.	Chance Penneystone.
Terrestrial and Fluviatile.	Downwards from the Chance Penneystone to the fungus coal inclusive.
2. *Marine* and Fluviatile.	Bas above the blackstone coal.
Terrestrial	Blackstone coal.
3. *Marine*, Terrestrial, and Fluviatile	Blackstone, ironstone.
Terrestrial	To the ballstone inclusive.
4. *Marine*? or Fluviatile.	Bas over top coal.
Terrestrial, Fluviatile ..	To the blue flats inclusive.

5. *Marine*, Terrestrial, Fluviatile ..... } White flat stone.
Terrestrial..... To flint coal bas.
6. *Marine*? or Fluviatile. Flint-coal bas.
Terrestrial ..... Flint-coal and underlying sandstone.
7. *Marine* and Fluviatile? Penneystone ironstone.
Terrestrial and Fluviatile. Strata below the Penneystone to the base of the coal-measures*.

These alternations necessarily lead to the inquiry—whether they were produced by oscillations of the land, whereby it was at one time submerged and covered with a stratum of silt containing marine exuviæ, and at another raised and converted into a marshy tract, overspread with a thick, luxuriant vegetation, and harbouring in its shallow waters numerous freshwater shells, to be again submerged and overlaid by another marine deposit,—or whether the phenomena cannot be accounted for by supposing, that the coal-measures were accumulated in an estuary, into which flowed a large river, subject to occasional freshes charged with the testacea peculiar to its waters and the vegetation of the adjacent districts.

In examining the various strata, we obtain in their lithological changes some clue to the transporting power of the water by which the beds were accumulated. As there is a remarkable difference in the range of organic remains, attended also by corresponding but minor changes of lithological structure between the northern and southern portions of the coal-field, it will be necessary, in describing the mode of deposit of the measures, to refer as nearly as possible to the central districts, where the principal phenomena of north and south are co-existent. The reader must bear in mind, that in the north of the coal-field at Donnington and Woombridge, the animal reliquiæ exhibit their greatest variety; that in proceeding south, they gradually decrease, the change commencing with those highest in the series; and that they eventually disappear with the Penneystone stratum at Broseley (see Plate XXXVII.): certain general lithological characters, subject, however, to considerable local variations, are co-extensive with these changes. When reference is made to local phenomena, it is always mentioned.

Immediately succeeding the marine deposit of carboniferous limestone are thick irregular beds of coarse sandstone, frequently passing into conglomerates, and containing a few impressions and casts of imperfect fragments of vegetables. They graduate upwards into fine sandstones and sometimes into shale. The crawstone, which occurs in one of these sandstones, contains numerous beautiful casts of the *Stigmaria ficoides*, of which the internal structure is sometimes preserved,

* The diagram of the coal-field, Pl. XXXVII., exhibits proofs of these alternations.

also several species of Unio—the first trace of animal life we meet with in the coal-measure. The same Stigmaria is also very common in the little flint-coal and sandstone above the crawstone.

The characters of this series, therefore, apparently indicate a period of considerable turbulence, or a sudden and violent change in the condition of the land succeeding a long period of repose, during which the carboniferous limestone had been formed.

In the lower strata the thick sandstones and conglomerates, the great and rapid changes in several beds at very short distances, and the local occurrence of one bed and the absence of others at greater distances, all indicate a period of much disturbance and sudden changes; but these signs of varying velocities gradually diminish as we ascend the series. Such effects we are naturally led to expect, if we consider the great difference between the characters of the coal-measures and those of the carboniferous limestone. In the latter, we have every indication of a formation gradually accumulated in the ocean during a lengthened period, whereas the structure of the former denotes the proximity of dry land, and bears evidence of violent operations by which one portion of the bed of the ocean became dry land, while another was partially raised and converted into an extensive estuary, receiving the detritus borne down by the rivers intersecting the newly-exposed land. The abrasion of the recently elevated tracts, then but barely covered with soil, may account for the prevalence of thick, unproductive, coarse sandstones in this lower division, while the presence of a few coal seams, and of the crawstone with its well-preserved specimens of delicate Stigmaria, higher in the series, may have arisen from a more abundant growth of plants during a period of calm, succeeding the first effect of the change of level. The recent origin of the estuary and the violent action attendant upon the transport of the conglomerate, would account for the absence, in the lowermost beds, of marine Testacea.

The next series of strata, extending from the clod-coal to the Penneystone, consists, in the lower portion, chiefly of thick beds of shale, containing large quantities of finely-preserved vegetable remains, and alternating near the bottom very frequently with seams of coal. In the south of the coal-field some of the shales pass into sandstones, which always inclose an increased number of plants in passing from a fine to a coarser grain. This point appears to me to be important, and to prove either a greater supply of vegetable remains from a body of water more widely extended and of greater transporting power, or a more complete decay in the plants from the slower accumulation of the fine-grained sandstone. The coal-beds are far more persistent in this than in other portions of the coal-measures. Each bed is generally underlaid by a thin seam of indurated clay, containing few or no fossils; whereas the overlying stratum succeeding the few inches of fine bituminous shale, immediately incumbent on the coal, is coarser and thicker and abounds in vegetable casts and impressions, which decrease rapidly in number as the distance from the coal increases. From these facts, I would infer, that the lower clay and shale were gently washed down during short periods of calm, and of rapid vegetation, and that the overlying coarser silt and sand were accumulated by increased volume and violence in the current, consequent upon the floods which originated the coal seams. It nevertheless appears probable, that no lengthened period elapsed between the uprooting of the plants and their entombment, for the casts and impressions in some of the roofs of the coal-bed, exhibit perfectly the delicate external organization of several genera of ferns and Lycopodiceæ, and sometimes retain a portion of their vegetable tissue. The period, therefore, during which this series was deposited, seems to have been one of repeated but not violent changes.

Thus far, in the portion of the lowest measures which we have reviewed, the unsettled state of the land and water appears to have checked the increase of animal life. We now, however, ar-

rive at a deposit, the Penneystone, indicating a long period of repose. This ironstone measure, in its interesting fossils, unfolds to us the existence of numerous marine animals—the great Megalichthys, the Gyracanthus, the *Cyathocrinites quinquangularis*, together with a considerable number of Testacea*; but associated with them are a few large Unios, and remnants of vegetables. The slow accumulation, it is probable, totally prevented the preservation of the more delicate parts of plants, and permitted only small and worn portions of stems or branches, which resisted the lengthened exposure, to be preserved from destruction. So tardy was the accumulation of silt, as proved by the fine and homogeneous texture of the stratum, by the existence of shells in all stages of growth, and by their general and uniform dispersion, by the absence of the finer and more delicate parts of plants, and by the presence of parasitical animals attached to the remains of fishes and shells, that unless the body were encased in an ironstone nodule its decay appears to have been almost inevitable; for, as before mentioned, the fossils are, with rare exceptions, consisting chiefly of the scales and teeth of the Megalichthys, found solely in the ironstone nodules, and not in the shale. The numerous Coprolites attest the existence of many fishes. Yet where are their remains? Here and there only are a few preserved from that destruction to which long exposure most probably consigned the greater bulk of them.

A considerable interval seems to have elapsed between the accumulation of the Penneystone shale and the deposition of the overlying coarseish sandstone called the flint-coal flint; for in the north of the coal-field, thick tablets and large blocks of ironstone, containing a peculiarly crystalline compound of carbonate of iron and carbonate of lime called curlstone, lie on the top of the Penneystone shale; and in the same situation in the southern districts of Madeley and Broseley occur extensive tabular masses of conglomerate ironstone, varying in thickness from 1 to 12 inches, and consisting sometimes entirely of small white quartz angular pebbles, varying in size from a pin's head to a small marble, mixed with grains of white decomposed felspar, and imbedded in a matrix of ironstone, with which it occasionally forms thin alternating layers. This conglomerate also contains small rolled pebbles of ironstone, characterised by the fossils of the Penneystone measures.

We thus have proofs of a transition from a long period of calm and repose to one of some violence, which apparently was continued in a modified form during the deposition of the overlying stratum of sandstone; for upon leaving the Penneystone, we suddenly lose all traces of animal

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* Mr. T. Bell has recently called my attention to a singular fact connected with recent freshwater Testacea; viz. that in old shells the umbones of bivalves and the apices of univalves bear traces of erosion more or less according to the age of the animal. This circumstance appears to hold good in all cases except with light and fragile shells such as the Lymnea. Now it appears to me that this fact may be of considerable value as applied to the discrimination of marine and freshwater shells in a fossil state, and as a test whether several fossil shells supposed to be of freshwater origin, yet found in situations difficult to reconcile with that supposition, are to be considered indicative of the presence of freshwater—such as the extensive series classed as Unios. I have examined a considerable suite of shells, apparently belonging to this genus; but as they are all casts in ironstone, I have not been able to come to any very decided opinion; nevertheless, the greater number of specimens exhibited no trace of erosion, but a few, and amongst them several from the Penneystone, decidedly did.

life—the increased transporting power of the water accumulating thick beds of sandstone, and entombing large quantities of gigantic Sigillaria, Calamites, and Stigmaria. The vertical position of a few of the larger specimens, with their roots attached, does not mar the supposition of their having been transported, for the greater number of these fossils lie horizontally, or nearly so, and at all levels. The gigantic character of this Flora, so different from that of the other strata, appears to be a natural consequence of the long period of quiet during the accumulation of the Penneystone measure—a period during which the vegetation of the country flourished vigorously and uninterruptedly. May not part of the flint-coal which reposes upon this sandstone have been derived from the woody matter of the large vegetable casts entombed in the rock?

The flint-coal lies upon this sandstone, and is, in the central and northern districts, covered by a thin stratum of a very fine, dark, bituminous shale, containing a few scales and teeth of fishes, and generally, in its upper part, a band full of crushed Unios, resulting probably from a suddenly increased fluviatile action succeeding a period of calm. This is further confirmed by the interpolation between the shale and the white flat measure of a stratum of coarseish freestone or sandstone, occasionally conglomeratic, which commences at Ketley, and rapidly attains a thickness of several yards, affording almost the first indication of a strong local action from the north-westward, and forming a thick and irregular sedimentary deposit betwixt the regular and quiet accumulation of the flint-coal bass and the white flat measure, which stratum thins out northward of Ketley; but to the southward of Ketley is in immediate superposition with the flint-coal bass. It is in this portion of the coal-measures, that the important variations, both in the organic remains and in the lithological structure of the northern and southern districts, begin to show themselves distinctly.

The white flat measure, which then succeeds, again brings us to a period, when conditions prevailed somewhat similar to those under which the Penneystone measure was deposited. Though the epoch was probably of shorter duration, yet we here find several new species of the Trilobite family, and a large proportion of Unios and of plants, the more delicate parts of which are well preserved, indicating, probably, a greater rapidity of accumulation than in the Penneystone; whence the abundance of fluviatile, and the scarcity of marine Testacea.

The system overlying this stratum consists of numerous alternations of rather thick coal-seams, shale, and ironstone, and subordinate, fine-grained sandstones. The numerous remains of Sigillaria, Lepidodendra and other plants, generally associated with Unios, which occur sometimes, as in the blue flats, in great quantities,—the frequency of the repetition of the different strata, and their extensive and uniform persistence as far south as Lightmoor, appear to indicate many changes and extensive but not powerful floods.

Incumbent on the top coal, the highest in this last series, is a thin bed of fine bituminous shale, which again proves the existence of the Megalichthys and other fishes, probably marine, whose detached and scattered remains are preserved almost uninjured.

Next follows a deposit, apparently of rapid but tranquil accumulation, forming the ballstone measure, a stratum characterised by the delicacy and beauty of its Flora, and by the absence of animal reliquiæ. The impressions of the leaves of the Cyclopteris, Neuropteris, &c., are so perfect, that it is impossible to imagine the fronds could have been transported by violent currents, or that they could have been long exposed to the action of the atmosphere and the water. The slightly rumpled appearance of the delicate and unbroken tissue of the *Cyclopteris orbicularis*, the sharpness and distinctness of every fibre of the *Neuropteris gigantea*, and other plants, could only have resulted from an immediate and tranquil entombment.

The ballstone is overlaid by a series of thick beds of sandstone, with subordinate shales, and a few limited seams of coal. The lithological characters mark a period of some duration, disturbance, and change, with a few intervals of quiet, as during the deposition of the brick measure and the blackstone. In the latter deposit we again find a few marine and fluviatile Testacea associated with land plants.

At Donnington, the thin bed of fine bass above the blackstone coal contains numerous well-preserved Lingulæ, with other marine testacea and remains of fishes, indicating a nearly complete cessation of that fluviatile action, which in other parts of this series accumulated such quantities of Unios.

The strong and intermitting fluviatile action was prolonged upwards to the Chance Penneystone, where another considerable interval of calm occurred, during which marine Testacea again lived and multiplied, as is proved by the abundance of the *Leptæna scabricula*, associated with a few other marine Testacea and fishes.

The characters, above described, of the strata between the top coal and the Chance Penneystone are limited to the north of the coal-field, to which the accompanying coals and ironstones are almost entirely confined.

Above the Chance Penneystone,—the thick preponderating beds of sandstone,—the change in the mineralogical characters of several beds,—the scarcity of vegetable and animal remains, yet evidently with a continuation of a powerful aqueous action, probably resulted from a considerable mutation in the condition of the adjacent land, to which we shall recur shortly.

It will be now necessary to point out the principal changes of lithological characters and animal reliquiæ of the coal-measures in their horizontal range:

1st. The lower series of coals, up to the Penneystone, are tolerably persistent throughout, from Donnington to Broseley; but above that stratum, the coals and ironstones, with their associated marine reliquiæ, have a gradually diminishing horizontal range southward, so that the upper beds are limited to a small district in the north of the coal-field. (See Diagram, Plate XXXVIII.)

2ndly. The absence of organic remains in the Penneystone at Donnington, and the gradual and rather abundant appearance of marine reliquiæ, accompanied by a decreasing thickness of the stratum as it trends southward until it disappears at Broseley, deserve special notice. A narrow band of limestone, apparently of fresh-water origin, makes its appearance in that district higher in the vertical range of the measures.

3dly. Other changes, claiming particular mention, are the presence of numerous beds of red and variegated clays and marls, and calcareous sandstones, in the south-east of the coal-field, and the expansion of many of the shales and sandstones to the northward, with the abrupt thinning out of all the coals and ironstones above the Penneystone between Donnington and Lilleshall, accompanied by an increased importance in the upper series of soft conglomerates and sandstones.

4thly. It is necessary to mention the great variations of lithological character, and irregularity of range of almost all the arenaceous strata.

The conclusion, therefore, which I think may safely be drawn is, that the deposition of the coal-measures commenced immediately subsequent to some great convulsion altering the relative level of land and water; and—judging

from the peculiar lithological character, and the preponderance of large and aged corals in the carboniferous limestone, conjointly with its gradual thinning off in its range southward, indicating its accumulation in a tranquil and rather shallow sea, undisturbed by the immediate influx of any large river, yet evidently receiving, as the sea became deeper to the northward, a large supply of fine silt, perhaps from the northward—it is probable that the change consisted of a subsidence along the south-west shores of the sea in which the lower carboniferous limestone was accumulating; for had the movement been elevatory, a portion of the bed of the ocean, and consequently of the carboniferous limestone, must have been exposed, and outliers of that formation would most probably have existed at a distance from the coal-measures, which now, on the contrary, overlap its edges. Again, we could not expect to find in the detritus derived from land recently elevated from the bottom of the sea, remains of land plants; whereas these remains are extremely common, and we even find a thin and irregular bed of coal at the very base of the measures. We may consequently infer, that an extensive area experienced a considerable subsidence, depressing one portion beneath the sea, and materially modifying the physical geography of the remaining dry land, giving rise both to a new line of coast and to a new system of drainage, enlarging some rivers and forming others. No sooner, indeed, do we pass into the coal-measures, than we find, throughout their entire vertical range, evidences of strong river action in the presence of transported vegetables, of which the majority are, according to A. Brongniart, such as might be expected to have flourished on low and marshy lands; and fluviatile shells, intermingled with the marine Testacea of the sea into which they were drifted. From these great mutations would probably result—at first, barren conglomerates and coarse sandstones, succeeded by strata produced by a more fixed and settled order, as the effects of the preceding paroxysms were gradually softened down and effaced. Vegetation, it may be inferred, flourished on the land, and Testacea and fishes multiplied in the sea, during those intervals of disturbance arising from inundations and freshes of the river, which flowed probably from the south-westward, carrying its detritus into a sea, where the dispersion of it was apparently limited by a current from the northward.

While on this subject, a few remarks may be made on the debris forming he coal-measures, and on the origin of the ironstone. The fine-grained quartzose sandstones—the constantly recurring pebbles of white quartz—the general diffusion of mica, and occasionally of felspar and slate rocks, evidently denote an origin in the older stratified formations; whilst the red

clays and marls, with the subordinate calcareous seams of the southern districts, may have been derived from the old red sandstone and upper Silurian rocks.

We find the peroxide of iron distributed in a greater or less degree throughout the whole of the coal-measures; but it is in those beds of shale only which appear to have been formed gradually and slowly, that we find it in any great plenty. This proves the abundance of iron in the rocks from which the silt was derived. Now we know that all trap rocks contain more or less iron. Dr. Withering found in those of Staffordshire, 20 per cent.*; Klaproth, in those of Hazenberg, 20 per cent.†; and out of numerous specimens of basalt which he analysed, Bergman found, upon an average, as much as 25 per cent.‡. As the ironstone itself contains only about 33 per cent. of iron, it would require no very extensive degradation of trap rocks to produce a bulk of ironstone equal to the entire volume of that existing in the coal-measures; whilst the residual silica and alumina, in the proportion of about 73 of the former to 27 of the latter, give nearly the composition of the ironstone shales.

As a further support of this hypothesis, I have found, in several of the conglomerates of the coal-measures, traces of the debris of igneous rocks.

It has also been shown, that the carboniferous series frequently reposes upon beds of trap and basalt. From the soft and friable texture and rapid disintegration of many of these rocks, when exposed to the action of the atmosphere, they would admit of great abrasion, and afford ample materials for extensive beds of ironstone. The presence of titanium in the iron ore (see table of minerals, Appendix B.) tends to corroborate its derivation from these igneous rocks, as that metal is of very common occurrence in them. According to Mohs, sphene is found "in beds of syenite, and other trap rocks§." De la Beche states that "Basalt is supposed to be essentially composed of felspar, augite, and titaniferous iron||;" whilst Berthier says, "*mais c'est surtout dans les roches volcaniques, que le titane abonde; il y est toujours combiné avec le fer et le manganèse*¶."

It will readily be seen that the Coalbrook Dale coal-field differs greatly, both in its lithological character and its organic remains, from most of the English coal-fields. The latter are in general nearly destitute of animal reliquiæ, and exhibit but few conglomerate strata, whereas the former abounds in both.

* Conybeare's Outlines of Geology, p. 139. † Ure's Chemical Dictionary, 3rd edition.
‡ *Ibid.* § Mohs' Mineralogy, translated by Haidinger, vol. ii. p. 376.
|| Geological Manual, 1st edition, p. 122.
¶ Essaies par la Voie Sèche. Paris, 1834. Vol. ii. p. 112.

In the Coalbrook Dale field the mountain limestone has but a trifling comparative thickness; the millstone grit also is entirely wanting below the coal-measures; and as the organic remains present a far closer analogy to those of the carboniferous limestone of Yorkshire and Northumberland than to the coal-fields of those counties, it appears very probable, that this coal-field is of older date than most of those in the north and south of England.

The coal-fields to which it bears the closest resemblance are those of North Northumberland, Durham, parts of Yorkshire and Scotland. Many of the Conchifera and Crinoideæ, the Conularia, the Megalichthys and Gyracanthus, which characterise the Coalbrook field, are abundant in the subordinate beds of limestone and ironstone in the Scotch coal-fields.

Mr. Phillips, in his excellent Illustrations of the Geology of Yorkshire, divides the carboniferous formation into three groups, viz. the Millstone grit, the Yoredale series, and the Great Scar limestone, each characterised by peculiar but variable lithological composition, and, during the prevalence of like conditions, by organic remains of a generally similar character.

Upon comparing the sections of Wensley Dale, Whernside, Penyghent, and Coverdale* with that of Lilleshall (pp. 425, 427), the general similarity in lithological structure is very striking; there are the same alternations of arenaceous strata with subordinate limestones, characterised by the presence of numerous Polyparia, some Brachiopoda and Cephalopoda, but with very few Crinoidea. Again, the resemblance between the black limestone group of Yorkshire and that of Steeraways, both characterised by the presence of Lithodendra and large Leptænæ (Producta), induce me to consider the limestone strata of Lilleshall and Steeraways as the equivalents of the Yoredale series, which Mr. Phillips has shown to attenuate and become finer grained as it ranges southward.

Supposing, therefore, that these limestones represent the Yoredale series, or a portion thereof, it is probable, that the measures of Coalbrook Dale, which immediately succeed, are coeval or synchronous with the lower millstone grit, and that the variable fine conglomerates and concretionary shales, forming the upper portion of the coal-measures, and eventually throwing out the coals and ironstones in the north of the field, may be the representatives of the Upper Millstone or Brimham grit. The greater abundance than is usual in the millstone grit, of many marine remains of the limestone groups, might arise from the augmented vertical range, in this district, of those conditions suited to the existence of Testacea, and which prevailed during the

* See Phillips's Illustrations of the Geology of Yorkshire, Part II. pp. 37—57.

deposition of the lower series in the north of England; still, from the littoral and fluviatile character of the deposit, it is possible, that its interpolations of freshwater and land detritus with that of the oceanic currents, may have been prolonged during the whole remaining carboniferous era, and even have continued to that of the new red sandstone, for it has been shown that in parts of this district, the coal-measures appear to graduate upwards into the lower new red sandstone; and Mr. Murchison has proved that in most of the adjoining fields, there is a conformable transition between these two formations.

Upon the second point, which refers to the nature and effects of the disturbances, but little need be said. It has been shown in the observations upon the faults, that the whole of the Coalbrook Dale district has been protruded * through the new red sandstone, and that this angular promontory of uplifted rocks forms merely the extremity of the principal zone of the Silurian system described by Mr. Murchison. This form of the detached area is due apparently to the intersection of two lines of disturbance. The more important one constitutes the axis of the Wrekin, with its parallel longitudinal dislocations and anticlinal axes, ranging nearly S.W. and N.E.; the other trends rather N. of N.N.E.; and the intersection of these two converging lines gives rise to numerous diagonal, connecting dislocations.

We have no direct evidence of the precise period at which the dislocations were effected. It can only be stated, that they took place subsequent to the deposition of the Lower Red Sandstone system.

From the details in pages 447 and 457, and from the description of adjacent coal-fields by Mr. Murchison†, it is evident, that the coal-measures of Coalbrook Dale are but a part of an extensive deposit from which they have been disjointed and separated by great subterranean movements. Hence, we may infer, that a portion of that deposit still remains intact below the overlying formations of new red sandstone of Shropshire, Cheshire, and Staffordshire; and it is not improbable that, by other lines of disturbances traversing these counties, the coal-measures, although covered by the new red sandstone, may

* I use this word to signify merely the change, by subterranean agency, of the relative level of these two sedimentary deposits, as I consider that this effect being due to the contraction of the interior nucleus of the earth, the collapse of the strata resulting therefrom would produce a general and tolerably regular subsidence of large central areas, accompanied by the elevation, fracture, and tilting of narrow longitudinal segments; whence the strong lateral pressure evinced in the anticlinal axes and along the lines of fault, and the absence in this disrupted district of open fissures, such as would have resulted from the tension attendant upon an independent expansion of a portion of the interior nucleus.

† See Mr. Murchison's Silurian System, p. 79, *et seq.*

be, in some places, at no great depth from the surface. But lines of dislocation are traced with difficulty through that formation, the different strata of which are rarely characterised by fossil remains, or by any great dissimilarity of lithological structure.

Underlying the new red sandstone, these coal-measures would probably have remained yet for ages unknown, had not portions of them been broken off and uplifted, and this too in an order beautifully commensurate to the wants of man. A few seams of coal and ironstone cropping out to day, originally led to the discovery of a valuable deposit; and though the means of working them were then limited, yet was the supply easily attainable. In time, as the demand increased, so did the means multiply, and thus were successively brought into use, the gradual descending downcasts of the coal-measures, from the outcrop at the Steeraways, then over the Ketley fault to the Lightmoor fault, which delayed further progress for some time, but was at last passed; and now when that stage of the coal is exhausted, there appears every prospect, though at still greater depths, of a further supply, and probably equal to any with which we are yet acquainted*.

The third and last point claiming consideration, is the nature of the agents which have modified the surface of the country. It having been shown in p. 452 *et seq.*, that the disturbances which affected this district not only destroyed the continuity of the sedimentary deposits, but placed their fractured portions on widely different levels,—it follows, that if the surface had not been denuded, it would now present great irregularities, and even mountainous ridges, exceeding, in some instances, 2500 feet in height. The existing surface is, however, comparatively flat; and it is therefore evident, that, in the elevated central, western and southern districts, where only the lower divisions of the coal-measures remain—all the upper strata, amounting to not less than 800 feet, with at least the whole of the lower new red sandstone, which was probably more than 1200 feet thick, have been removed; and that in the valley of the Severn, as well as in that between Barrow and Shirlot Hills, not only have the new red sandstone and coal-measures been completely denuded, but also 500 feet of Wenlock rocks in the former instance, and 600 feet of old red sandstone in the latter.

Notwithstanding, however, the extent of these effects, still the diversity of

* The reader must not however infer, that coal and ironstone strata necessarily exist everywhere beneath the new red sandstone of the surrounding districts, because it has been shown, that although the coal formation, as a whole, may be extensively persistent, still from its littoral character all the terms of the series are liable to rapid variations. The coal and ironstone will be limited to an area, proportionate to the strength of the fluviatile currents.

hill and dale must be ascribed, as before stated, to the disturbances which have traversed every part of the district.

Whether the change of relative level and the subsequent denudation were effected slowly or violently, are questions too complex for me to investigate in this paper; but I am tempted to infer, from the superficial obliteration of the faults, that the change in the levels took place under water, and that the surface was long exposed to its action. I would also infer, from the debris of Silurian rocks distributed through the drift, that during its accumulation, currents flowed over the coal-field from the west and north-west.

Although the remains of Testacea in the gravel are scarce and much broken, still they suffice to prove the identity of the shells with those of existing species, and therefore to establish the recent withdrawal of the waters.

APPENDIX.

SECTIONS OF COAL PITS. (A.)

LIGHTMOOR WIMSEY PIT, 1788.

(From Plymley's Agricultural Survey of Shropshire.)

No.		Yds.	Ft.	In.
1.	A good loam and mixed soil (gravel and sand)	6	0	0
2.	Pale blue clunch	16	0	0
3.	Dark grey rock, not very strong	5	0	0
4.	Sky blue clunch	2	1	6
5.	Three sulphur coals, divided by pale blue earth, 2 in. between each	1	1	6
6.	Strong clod, mingled pale blue and red	16	0	0
7.	Brown rock (the sulphur coal rock)	7	1	0
8.	Three sulphur coals, divided by pale blue earth, 4 or 5 in. between each	3	0	0
9.	Blue clunch	4	2	0
10.	Pale red clunch	4	0	0
11.	Rough rock (full of dark brown hard pebbles and ironstone)	7	0	0
12.	Bind (pale blue clod)	14	0	0
13.	Stone clod (ditto) in which lies a bed of ironstone called ballstone	5	0	0
14.	Black slate	0	1	0
15.	Coal (top coal, exceeding good fuel)	1	1	0
16.	Top coal tough (a dark blue earth and a very heaving measure)	0	1	0
17.	Coal, called the foot coal	0	1	0
18.	Slums* (black slaty earth and a heaving measure)	2	0	0
19.	Coal (the three-quarters coal)	0	2	0
20.	Rotch (dark grey hard rock)	0	2	0
21.	Coal (the double coal)	1	0	0
22.	Dark grey clod, will fire from its own nature	2	0	0
23.	Coal (yard coal)	1	0	0
24.	Blacks (a black slate coal and rock all mixed together)	2	1	6
25.	Clod (a pale white, in which lies a bed of ironstone called the spar ironstone)	2	0	0
26.	Flan (a dark slate)	0	0	6
27.	Coal (upper flint coal)	1	1	6
28.	Upper flint (a hard grey rock)	7	1	0
29.	Penney measure (a pale blue clod, in which lies a large quantity of small balls of ironstone called the Penney ironstone)	5	1	6
30.	Sulphur coals (3 beds, divided by 3 or 4 in. of dark brown earth)	1	9	0
31.	Pale blue clod	2	0	0
32.	Coal (the silk coal)	1	2	0
33.	Clunch of a dark blue	5	1	6
34.	Coal (the silk coal, divided by a few inches of grey earth)	0	1	6
35.	Clunch of a dark blue, with coal in the middle 17 in. thick, (the coal is called silk-coal)	3	1	10
36.	Coal (the two-foot coal)	0	2	0
37.	Linseed earth (dark brown, a very shuttle measure)	0	1	2
38.	A black slate	0	0	6
39.	Coal (the best coal)	0	1	6
40.	Black bass or slate	0	0	6
41.	Coal (the middle coal)	0	2	9
42.	Dark brown strong clod	1	0	6
43.	Coal (the clod coal)	0	1	10
44.	Clod of a pale blue	1	1	8
45.	Coal (the little flint coal)	0	2	2
46.	Little flint (a rock of a dark grey mingled with pebbles and ironstone)	16	0	0
		154	1	4
47.	Die earth, a pale blue hard clunch (Wenlock shale) said to be	100	0	0

TRIAL PIT, CASTLE GREEN.

1.	Surface to great flint	6	1	6
2.	Great flint rock	6	0	0
3.	Penneystone	3	0	0
4.	Sulphur coal	0	1	6
5.	Upper clunches, with an ironstone and two smut coals	14	2	3
6.	Sill coal	0	1	6
7.	Clunch	0	1	8
8.	Vigor coal	0	0	10
9.	Ganey rock	0	0	8
10.	Ganey coal	0	2	3
11.	Linseed earth	0	1	0
12.	Best good, not good	1	0	0
13.	Middle and clod coal gob (from which the coal is removed)			
14.	Clunch	1	0	3
15.	Little flint coal	0	2	0
		36	0	5

SECTIONS AT WOOMBRIDGE PITS. By Dr. Townson.

See Townson's Tracts, p. 166.

No.			Yds.	Ft.	In.
1.	Top rock	Argillaceous yellowish sandstone	9	0	0
2.	White clay	Blackish grey plastic clay	6	0	0

* For an explanation of the principal local terms, see *ante*, p. 430.

No.			Yds.	Ft.	In.
3.	Chance coal	Common coal	0	0	9
4.	White tough	Blackish grey plastic clay	0	2	0
5.	Ash ball rock	Mixture of small fragments of greenish grey clay, reddish chert, and white quartz	6	0	0
6.	Rocky marl	Reddish brown dry shivery clay	6	0	0
7.	Gritty rock	White, very fine or compact sandstone	2	0	0
8.	Rocky marl	Similar to No. 5, but of much minuter parts, and mixed with some of the red clay of No. 6.	4	1	0
9.	Gritty rock	Fine grey sandstone containing mica	1	2	0
10.	Rocky marl	Reddish brown clay and whitish clay mixed nearly the same as No. 6.	3	0	0
11.	Gritty rock	Whitish sandstone	1	1	0
12.	Ash ball measure	Similar to No. 8, but without the red clay	28	0	0
13.	White rock	Very fine white sandstone	1	0	0
14.	Rocky marl	Similar to No. 8.	3	2	0
15.	Rock	Very fine sandstone, like No. 7.	0	2	0
16.	Tough soft clay	Blackish grey plastic clay	0	1	6
17.	Hard rock	Grey, very fine or compact sandstone, containing minute particles of mica	1	1	0
18.	Top Penney measure	Beds and nodules of ironstone in blackish grey dry clay	2	2	0
19.	Black slums	Greyish black slippery dry clay	0	1	6
20.	Fungous coal rock	Coarse, whitish sandstone	12	0	0
21.	Fungous coal	Excellent coal	1	0	0
22.	Fungous coal poundstone	Greyish black dry clay	1	1	0
23.	Foot coal	Not got	0	1	0
24.	Black stone	Blackish ironstone in nodules, in a greyish black dry clay	1	1	0
25.	Stone coal	Good coal.	1	1	0
26.	Tough poundstone	Black slippery dry clay	1	0	0
27.	Gur coal	Not got	0	2	0
28.	White clunch	Blackish grey dry clay	1	1	0
29.	Grey rock	Light grey fine sandstone	1	1	0
30.	Brick measure	Alternating strata of grey ironstone and dry clay	5	1	0
31.	Bind bass	Black dry clay	2	0	0
32.	Bind	Brownish grey, very fine, argillaceous sandstone	2	1	0
33.	Ballstone	Grey nodular ironstone in dry clay. The nodules contain vegetable impressions	3	0	0
34.	Dun earth	Ironstone nodules in a grey dry clay	2	0	0
35.	Top coal bass	Black indurated schistose clay (schiefer Thon.)	0	0	4
36.	Top coal	One of the best coals in Shropshire	1	2	0
37.	Top coal poundstone	Greyish black dry slippery clay	0	1	0
38.	Slums	Black slippery dry clay	1	1	0
39.	Three-quarter coal	Never got	0	2	0
40.	Double coal rock	Very fine whitish sandstone	2	0	0
41.	Double coal	Good coal, much used	2	0	0
42.	Double coal poundstone	Greyish black dry clay	0	1	6
43.	Yellowstone	Ironstone in short thick masses in a shivery blackish grey dry clay. It contains in its cavities blende and "terra ponderosa vitriol"	2	0	0
44.	Yard coal	Sometimes got	1	0	0
45.	Yard coal poundstone	Black dry clay resembling bass	0	0	9
46.	Quoice neck	Greyish black dry clay with very shining surfaces	0	0	9
47.	Blue flat	Strata of brownish grey ironstone in dry clay, in the upper part nodular	2	0	0
48.	Pitcher basses	Black bass or indurated schistose clay (schiefer Thon.) like No. 36.	1	2	0
49.	White flat	Beds of ironstone in a black grey shivery dry clay	1	1	0
50.	Flint coal rock	Fine whitish sandstone, with some mica	3	1	0
51.	Flint coal roof	Blackish grey dry clay	4	1	0
52.	Flint coal	Good burning coal; at Madeley Wood it is charged with salt water	1	2	0
53.	Flint	Fine grained whitish sandstone, used for building	7	0	0
54.	Penney measure	Blackish grey dry clay, containing iron nodules; in the upper part of this stratum, close under the flint, the coal is found	8	0	0
55.	Sulphur coal	Coal, containing a great quantity of pyrites, which are used for vitriol; being cheap it is chiefly consumed in burning brick, lime, &c.	1	2	0
56.	Sulphur coal bass	Greyish black dry clay	0	1	6
57.	Upper clunch coal	Good coal, but being thin is not got except when the coal above is worked open	0	0	10
58.	Upper clunch	Light grey shivery clay, much used for fire bricks	1	0	0
59.	Clunch coal	Never got	0	2	0
60.	Lower clunch	Grey dry clay used for fire bricks	2	0	0

No.			Yds.	Ft.	In.
61.	Two-foot coal	Sometimes got	0	2	0
62.	Linseed earth	Black grey dry clay, used for fire bricks	4	0	0
63.	Best coal	This is the best coal; in the northern part it is 9 inches; but in the southern	0	2	0
64.	Randle coal	Is the best smiths' coal	1	0	0
65.	Bannock	Brownish grey very slippery dry clay, good for fire bricks	0	2	0
66.	Clod coal	Used for smelting in all the Shropshire iron	1	1	0
67.	Pale blue clod	Bluish grey clay with vegetable impressions	1	1	6
68.	Sandstone	Fine argillaceous sandstone, containing vegetable impressions	3	0	0
69.	Little flint coal	Good burning coal	0	2	0
70.	Little flint	Very fine white sandstone	3	1	0
			179	0	11

LITTLE WENLOCK.

No.		Yds.	Ft.	In.
1.	Clay	4	0	0
2.	Yellowstone earth	7	0	0
3.	Bind	5	0	0
4.	Ballstone	2	0	0
5.	Top coal	2	0	0
6.	Clod	0	1	0
7.	Foot coal	0	1	0
8.	Basses	0	2	0
9.	Three-quarters coal	0	2	0
10.	Rotch	0	1	0
11.	Double coal	2	0	0
12.	Ground coal	0	2	0
13.	Yard coal	1	0	0
14.	Basses	3	0	0
15.	Flint coal rough	1	1	0
16.	Flint coal	2	0	0
17.	Flint rock	5	0	0
18.	Penneystone measure	8	0	0
19.	Sulphur coal	2	0	0
20.	Upper clunches	2	0	0
21.	Sill coal	0	2	6
22.	Lower clunches	2	0	0
23.	Lower sill coal	0	1	0
24.	Rock	0	1	6
25.	Two foot coal	0	2	0
26.	Randle coal rock	1	1	0
27.	Randle coal	1	0	0
28.	Rough clod	4	0	0
29.	Clod coal	2	0	0
30.	Clod	1	1	0
31.	Rock	4	0	0
32.	Little flint coal	0	2	6
		68	0	6

NEW WORKS. NEW LAWLEY.

1.	Brick measure bind	3	0	0
2.	Brick measure	3	0	0
3.	Black basses	1	1	6
4.	Ballstone bind	1	1	0
5.	Ballstone measure	2	1	6
6.	Black basses	0	0	6
7.	Top coal	1	2	0
8.	Half-yard coal	0	1	6
9.	Double coal rock	0	1	3
10.	Double coal	2	0	0
11.	Basses	0	0	6
12.	Bind	0	1	6
13.	Basses	1	0	0
14.	Yellowstone	0	1	6
15.	White flat roof	1	0	0
16.	White flat measure	7	0	0
17.	Flint coal	1	1	6
18.	Flint	7	0	0
19.	Penneystone	9	0	0
20.	Sulphur coal	2	0	0
21.	Bind	0	0	6
22.	Upper clunches	5	0	6
23.	Lower clunches	1	2	6
24.	Sill coal	0	1	0
25.	Two-foot coal rock	1	2	6
26.	Two-foot coal	1	0	3
27.	Rock	1	0	6
28.	Best coal	0	1	10
29.	Randle coal	0	1	10
30.	Clod coal rock	3	0	0
31.	Bannock	0	1	0
32.	Smithies and hard coal	0	0	9
33.	Clod coal	1	0	0
		66	0	11

LODGE PIT, MADELEY.

		Basset Pit.			Deep Pit.		
		yds.	ft.	in.	yds.	ft.	in.
1.	Soil	0	1	6	0	1	8
2.	Clay	1	0	4	1	0	4
3.	Good sand	5	0	6	5	1	0
4.	Brick clay	4	2	0	4	2	0
5.	Tile clay	1	1	0	1	1	4
6.	Upper part of the rough rock	3	0	5	3	0	0
7.	Peldon pebbly	0	2	6	1	0	4
8.	Lower part of the rough rock	10	0	4	10	1	0
9.	Heaving earth	6	0	2	6	2	0
10.	Big flint	6	1	0	6	1	0
11.	Penney measure	2	0	4	2	0	4
12.	Pricking	0	0	6	0	0	6
13.	Clunch	0	1	0	0	1	4
14.	Sulphur coal	0	1	0	0	1	2
15.	Viger coal rock	3	2	0	4	0	6
16.	Viger coal	0	1	0	0	0	8
17.	Two-foot rock	8	2	0	9	0	3
18.	Two-foot coal	0	2	1	0	2	3
19.	Pricking	0	0	4	0	0	4
20.	Ganey coal rock	3	2	6	4	0	2
21.	Little Ganey coal	0	0	9	0	0	9
22.	Clod	0	1	0	0	1	0
23.	Ganey coal stone	0	0	3	0	0	3
24.	Ganey coal	0	2	1	0	2	1
25.	Pricking	0	0	4	0	0	4
26.	Best coal rocks	3	0	0	3	1	4
27.	Best coal	0	2	0	0	2	0
28.	Bass	0	0	9	0	0	9
29.	Middle coal	0	2	6	0	2	6
30.	Clod coal gob (the refuse thrown into the space from which the coal has been removed)	0	1	2	0	1	2
		66	0	4	69	0	4

INET, NEAR BROSELEY.

No.		Yds.	Ft.	In.
1.	Rock and clunch	14	0	0
2.	Coal	0	1	0
3.	Clunch	8	0	0
4.	Two foot coal	0	2	0
5.	Clunch	4	0	0
6.	Ganey coal	0	2	0
7.	Fire clay	4	0	0
8.	Top coal	0	2	0
9.	Clod	0	0	6
10.	Best coal	0	2	8
11.	Fire clay	0	1	0
12.	Clod coal	0	2	0
13.	Rock	5	2	0
14.	Flint coal	1	0	9
		41	0	11

AMIES FIELD, NEAR BROSELEY.

1.	Clays	6	0	0
2.	Clod	0	1	0
3.	Rock soft	0	1	6
4.	Clod	0	1	0
5.	Rock	0	0	6
6.	Clod	0	1	2
7.	Rock	3	1	6
8.	Clod	11	0	0
9.	Dingle rock	9	2	8
10.	Clod, with four small sulphur coals in same	27	1	6
11.	Rock	1	1	6
12.	Blue clod	6	2	0
13.	Soft rock	9	1	6
14.	Strong rock	5	2	0
15.	Lime rock (*Freshwater limestone.*)	1	1	0
16.	Blue clod	1	0	0
17.	Red clod	1	0	0
18.	Sulphur coal rock	6	0	0
19.	Sulphur coal roof	2	0	0
20.	Sulphur coal	0	2	6
21.	Sulphur coal Poundstone	2	1	6
22.	Brick and Tile clays	7	1	6
23.	Ganey coal rock	7	0	0
24.	Clod	7	0	0
25.	Best coal rock	5	1	6
26.	Best coal	1	0	4
27.	Middle coal	1	0	0
28.	Clod coal	0	1	8
29.	Pricking	0	1	0
30.	Clod coal Penneystone	1	0	0
31.	Black clod	0	2	3
32.	Hard stone	1	0	0
33.	Flint coal	1	0	0
		132	1	1

SNEDS-HILL.*

Depth in Yds. to the				
55.	Fungous coal	1	0	0
58.	Stone coal	1	0	0
93.	Brick measure	1	0	0
102½.	Ballstone	2	0	0
105.	Top coal	1	1	6
100½.	Double coal	2	0	0
116.	Yellowstone	1	0	0
117.	Yard coal	1	0	0
120.	Blue flat	2	0	0
124½.	White flat	2	0	0
126.	Flint coal	1	1	6
133.	Penney measure	7	0	0
140.	Sulphur coal	1	1	0
144.	Clunch coal	1	0	0
150.	Two-foot coal	0	2	6
151½.	Randle coal	1	0	0
154.	Clod coal	1	0	0
160.	Little flint coal	0	1	8

LANGLEY.

1.	Soil	0	2	9
2.	Red clay	1	0	2
3.	Brown shivery rock	3	1	4
4.	Blue clod	0	2	6
5.	Brown rock	1	2	5
6.	Blue clod and stone	2	0	0
7.	Red fire clay	0	2	7
8.	Tarey rock	0	0	6
9.	Blue clod and stone	1	0	6
10.	Yellow rock	4	0	4
11.	Blue clod	0	1	4
12.	Black rock	3	0	4
13.	Brown rock	4	1	2
14.	Blue clod	2	1	3
15.	Peldon with joints	2	0	6
16.	Blue clod	0	1	0
17.	Calaminker, red and white	0	2	0
18.	Blue clod	1	0	4
19.	Red clod	1	0	0
20.	Blue binds	9	0	9
21.	Calaminker	5	0	10
22.	Blue binds	8	0	8
23.	White rock	3	2	7
24.	Sulphur rock	8	2	8
25.	Sulphur rock coal	0	0	5
26.	Fire clay	0	0	8
27.	Chance coal	0	0	9
28.	Fire clay	0	1	10
29.	Chance coal	0	0	11
30.	Rough binds	3	2	0
31.	Red clod	0	2	1
32.	Rough binds	2	2	1
33.	Red clod	0	1	6
34.	Rough binds	3	2	6
35.	Red clod	1	0	6
36.	Espley rock	1	1	9
37.	White binds	5	2	6
38.	White binds	0	0	6
39.	Black bass	0	1	0
40.	Grey rock	0	1	1
41.	Blue binds	5	0	3
42.	Blue clod	1	1	0
43.	Tator butts, clod with stone	0	0	6
44.	Brickman's measure	3	1	6
45.	Slums	0	0	5
46.	Chance coal	0	0	4
47.	Rough rock	0	1	6
48.	Peldon	2	2	5
49.	Black rock	7	2	8
50.	Binds	4	0	2
51.	Red clod	1	0	4
52.	Fire clay	4	2	6
53.	Double coal rock	1	0	0
54.	Slums	1	0	0
55.	Yellowstone	1	2	0
56.	Yard coal	0	2	4
57.	Quoiceneck	0	1	2
58.	Blue flats	0	1	10
59.	Pitcher bass	1	2	0

* Only the beds of coal and ironstone are given in the section.

No.		Yds.	Ft.	In.
60.	Black	0	1	3
61.	White flats	2	2	7
62.	Flint coal	1	0	3
63.	Flint	11	0	0
64.	Penney measure	6	0	0
65.	Sulphur coal	1	0	4
66.	Over clunches	8	0	0
67.	Sill coal	0	0	10
68.	Lower clunches	5	0	0
69.	Two-foot coal	0	2	0
70.	Linseed earth	1	1	0
71.	Best coal	0	1	8
72.	Bass	0	0	6
73.	Randle coal	1	0	0
74.	Bass	0	0	3
75.	Clod coal	0	2	3
76.	Poundstone	1	2	0
77.	Rotch	1	0	0
78.	Little flint	4	2	0
79.	Little flint coal	0	2	0
80.	Crawstone rock	3	2	0
81.	Crawstone rock coal	0	0	9
		250	0	2

LODGEWOOD, NORTH OF DONNINGTON.

1.	Dun earth	66	2	0
2.	Penneystone rock	1	1	6
3.	Chance penneystone	2	0	0
4.	Small sulphur coal	0	0	6
5.	Seven yard rock	6	2	0
6.	Meatals	2	0	0
7.	Rock	7	2	3
8.	Dun earth	1	0	5
9.	Bass	0	0	9
10.	Fungous coal	1	0	8
11.	Coal poundstone and ragged robins	2	1	7
12.	Foot coal	0	1	6
13.	Blackstone	1	2	8
14.	Spladers	1	0	6
15.	Stone coal bass	1	1	0
16.	Stone coal	1	0	3
17.	Meatals	1	1	4
18.	Gur coal	0	2	4
19.	Grey	7	2	4
20.	Brick measure	2	1	4
21.	Bind bass	3	1	6
22.	Bind rock	3	2	4
23.	Ballstone	4	1	0
24.	Dun earth	2	1	6
25.	Top coal bass	0	1	0
26.	Top coal	1	2	7
27.	Slums and foot coal	0	2	10
28.	Top of double coal rock	0	1	5
29.	Three quarter's coal	0	2	0
30.	Lower part of double coal rock	0	1	10
31.	Double coal	1	2	10
32.	Double poundstone	0	2	0
33.	Yellowstone	2	0	8
34.	Yard coal	0	2	11
35.	Poundstone	0	1	0
36.	Quoiceneck	0	1	10
37.	Blue flat rock	0	1	0
38.	Blue flat bass	0	0	10
39.	Blue flat	1	0	0
40.	Pitcher basses	1	0	3
41.	Coal	0	0	5
42.	Flint coal rock	6	0	0
43.	Meatals	4	0	2
44.	Bass	0	1	4
45.	Flint coal	1	1	10
46.	Meatals	2	2	0
47.	Penneystone rock, and Glassonstone	6	1	7
48.	Penneystone rock, under Glassonstone	1	0	0
49.	Penneystone	10	1	2
50.	Sulphur coal	2	1	0
51.	Clunches	3	0	6
52.	Clunch coal	1	0	4
53.	Lower clunches	1	0	2
54.	Two-foot coal	0	2	4
55.	Meatals	1	0	8
56.	Best coal	0	1	6
57.	Linseed earth	2	2	0
58.	Randle coal	1	0	1
59.	Bannock	1	2	11
60.	Clod coal	0	2	4
		188	0	7

TRIAL PIT, NEAR LILLESHALL OLD HALL.

1.	Wild red ground	27	0	0
2.	Red slum	7	0	0
3.	Hard blue rock	1	1	6
4.	Rock	4	0	0
5.	Bind rock	1	0	0
6.	Brown clod and soft rock	12	0	0
7.	Red slum rather gritty	8	0	0
8.	Clod	3	1	6
9.	Coal mush and clod	1	1	6
10.	Mixed clod and rock	3	1	6
11.	White sandy rock	17	0	0
12.	Thin coal and white clod	5	0	0
13.	Hard white rock	5	0	0
14.	White rock and thin ironstone	3	0	0
15.	Coal	0	0	6
16.	Hard clunch	4	0	0
17.	Blue rock binds	6	0	0
18.	Red clod with raddle	2	0	0
19.	Flint rock	5	0	6
20.	Glassonstone	2	1	7
21.	Penneystone measure	10	1	2
22.	Sulphur coal	1	2	0
23.	Upper clunches	3	0	6
24.	Clunch coal and bass	1	0	4
25.	Lower clunches	1	0	1
26.	Two-foot coal	0	2	4
27.	Linseed earth and bass	3	0	8
28.	Randle coal	1	0	1
29.	Bannock	1	2	11
30.	Clod coal	0	2	4
31.	Poundstone and soft blue clod	5	0	0
32.	Little flint coal	0	2	0
33.	Crawstone	0	1	0
34.	Hard white grit with red veins	2	0	0
35.	White slaty grit rock	5	0	0
		157	0	0

WOOMBRIDGE BELOW THE FLINT COAL.

1.	Flint	7	0	0
2.	Penney measure	8	0	0
3.	Sulphur coal	2	0	0
4.	Slums	0	1	0
5.	Foot coal	0	1	0
6.	Over clunches	1	1	6
7.	Two foot coal	0	2	0
8.	Pricking	0	1	0
9.	Lower clunches	4	1	6

No.		Yds.	Ft.	In.
10.	Best coal	0	1	0
11.	Linseed earth	1	0	0
12.	Randle coal	1	0	0
13.	Clod coal and bannock	1	1	6
14.	Clod coal poundstone	0	1	6
15.	To the little flint coal	29	0	0
		58	0	0

PIT IN EDWARD'S PIECE, HADLEY.

1.	Cat brain	24	0	0
2.	Essball rock	19	0	0
3.	Four-foot coal	2	0	0
4.	Brown clod	1	1	0
5.	Black clod or clunch	4	2	0
6.	Coal	0	0	9
7.	Funker's rock	8	0	0
8.	Bass	0	0	6
9.	Funker's coal	1	0	3
10.	Funker's coal poundstone	0	2	0
11.	Bass	0	2	0
12.	Two foot coal	0	2	0
13.	Blackstone measure	1	2	0
14.	Stone coal	0	2	8
15.	Clunch or slums	2	0	0
16.	Gur coal	0	1	0
17.	Clunch	6	0	0
18.	Grey rock	3	2	0
19.	Brick measure	2	1	0
20.	Bind bass	1	0	3
21.	Bind	7	1	0
22.	Ballstone clod	4	0	0
23.	Top coal bass	0	1	0
24.	Top coal	1	1	6
25.	Slum	1	0	0
26.	Double coal rock	2	1	6
27.	Double coal	0	2	10
		98	0	3

ROUGH PARK ENGINE PIT.

	Depth to little flint coal	57	1	6
	Flint coal	1	0	0
		58	1	6

AN OLD WORK AT DAWLEY.

1.	The mount and sile (soil) and red stuff.	3	1	0
2.	The upper rock	3	2	0
3.	Between the upper rock and smut	3	2	6
4.	The ironstone measure blue stuff	1	0	0
5.	The rock brown and jointy, the lower part crudley	10	0	0
6.	The white stuff under the rock	2	1	0
7.	Red stuff, very tough	3	2	6
8.	Thin white stuff	11	2	6
9.	The rock and white stuff, and a great deal of water.	6	2	0
10.	Coal four inches thick, the stuff between the coal is two feet thick, and the lower coal is eight inches thick	1	0	3
11.	Tough white	0	2	3
12.	White	2	0	0
13.	Brown	1	0	0
14.	White hard	2	0	0
15.	Red	1	0	0
16.	White pimpley	1	0	0
17.	Red	1	0	8
18.	Blue pimpley	5	0	0
19.	Mingled red	1	2	8
20.	Big casing in the white	0	2	0
21.	From the casing to the hard in the rock	7	0	6
22.	Hard slice in the sulphur rock	1	0	6
23.	To the hard stones at the top of the coals	5	1	9
24.	Coal and stone	0	2	3
25.	Between the coals	1	0	0
26.	Coal	0	0	4
27.	Blue at the bottom of the casing	0	1	4
28.	Blue to the red	2	1	0
29.	Red	4	2	0
30.	Rough rock	6	1	0
31.	The calaminker earth	6	0	0
32.	White rock and bind	15	0	0
33.	Top coal and slums	2	2	4
34.	Double coal and rock	1	2	0
35.	Heaving earth	4	1	0
36.	Black and white clod and bottom coal.	8	0	0
		131	1	4

WOOMBRIDGE, PIT NEXT THE ENGINE.

1.	Earth and cat brain of various thickness	4	0	0
2.	Top rock	7	0	0
3.	Bind bass	0	1	6
4.	Bind	4	0	0
5.	Ballstone and earth	2	2	0
6.	Short earth	3	0	0
7.	Top coal bass	0	1	0
8.	Top coal	1	2	0
9.	Top coal and poundstone	0	1	0
10.	Slums	0	1	6
11.	Foot coal	0	1	0
12.	Three-quarters coal	0	2	3
13.	Rock	1	1	4
14.	Double coal	2	0	0
15.	Double coal poundstone	0	1	6
16.	Yellowstone earth and stone	2	0	0
17.	Yard coal	1	0	0
18.	Yard coal poundstone	0	1	0
19.	Quoiceneck	0	1	0
20.	Blue flat stone earth and stone	1	1	6
21.	Pitcher basses	1	1	6
22.	Flint coal rock	3	2	0
23.	Flint coal roof	3	0	0
24.	Flint coal	1	1	6
		43	2	7

OLD WATER PIT IN THE ROUGH PARK.

1.	Surface to the sulphur coal	9	0	0
2.	Sulphur coal	1	1	6
3.	To the rock	3	1	0
4.	Rough rock	4	1	6
5.	Calaminker	0	2	9
6.	Brown rock	11	2	0
	Lower coals—not given.			
	Depth to the little flint coal	42	1	6
		73	1	3

LIMESTONE PIT, LINCOLN HILL.

1.	Made ground	14	0	0
2.	Clay	1	2	6
3.	Gravel and sand	4	1	0
4.	Smut	0	0	9
5.	Clunch	0	2	0
6.	Flint coal	1	0	2
7.	Flint coal flint	6	2	0
8.	Crawstone measure	1	1	0

No.		Yds.	Ft.	In.
9.	Crawstone measure crust	0	1	8
10.	Rock	3	1	6
11.	Coal smut	0	0	9
12.	Clunch with balls of sandstone	4	0	0
13.	Lancashire ladies' coal	0	0	6
14.	Strong clunch with sandstone balls	6	1	0
15.	Sandstone rock	3	1	6
16.	Chalkstone	4	0	0
17.	Limestone (*Wenlock*)	9	1	6
		61	2	10

HEMAN'S PIT FIELD, NEAR BROSELEY.

1.	Soil and gravel	2	0	0
2.	Red sandy rock	7	1	0
3.	Ironstone	0	0	3
4.	Blue clunch	1	1	3
5.	Sulphur coal	0	0	6
6.	Blue clunch interspersed with small ironstone	4	2	4
7.	Sulphur coal	0	0	4
8.	Breccia. Blue bind	5	2	6
9.	Mingled red, brown and white	2	1	0
10.	Strong blue clunch	5	2	6
11.	Rock	0	2	6
12.	Stone and coal pricking	0	1	6
13.	Blue clunch and rock	4	2	3
14.	Bright hard coal	0	0	9
15.	Clunch	2	2	6
16.	Clunch mixed with rock	4	0	6
17.	Bass and smut	0	1	0
18.	Clunch	1	1	0
19.	Coal	0	0	9
20.	Clunch	1	0	6
21.	Rock	1	2	6
22.	Clunch	5	1	6
23.	Red clay	1	0	6
24.	Clunch and rock mixed	2	1	0
25.	Rock brown and pitchy	2	2	0
26.	Limestone (makes brown lime)	1	0	4
27.	Brown rock	0	2	2
28.	Ironstone	1	0	3
29.	Red, white and yellow	1	2	0
30.	Blue rock and clunch	10	1	6
31.	Clunch	1	2	0
32.	Coal	0	0	4
33.	Pricking	0	0	9
34.	Coal	0	0	7
35.	Clod	0	0	9
36.	Sulphur coal	0	1	7
37.	Pricking	0	0	6
38.	Coal	0	0	6
39.	White rock	1	2	0
40.	Py'd Rock	4	0	0
41.	Rough pitchy rock	13	0	0
42.	Ironstone (Penneystone)	1	1	0
43.	Red, blue and white	4	2	0
44.	Smut and coal	0	0	2
45.	Clunch	2	0	0
46.	Rock full of fractures	4	2	6
47.	Ganny coal	0	1	6
		110	0	10

YEW TREE PIT, CALCUT FIELD, BROSELEY.

1.	From the surface to the coal rock	18	0	0
2.	The day rock, or sulphur coal rock	8	0	0
3.	Sulphur coal	1	0	0
4.	Brick and tile clay	4	0	0
5.	White rock	12	0	0
6.	Top coal measure to the bottom flint coal	14	0	0
7.	Bottom coal	1	0	0
8.	Bottom coal flint	6	0	0
9.	Penneystone measure	2	0	0
10.	Viger rock	6	0	0
11.	Viger coal	0	1	6
12.	Rock	8	0	0
13.	Two-foot coal	0	1	6
14.	Ganny coal rock	4	0	0
15.	Ganny coal	1	0	0
16.	Best coal rock	6	0	0
17.	Best coal	2	0	0
18.	To the clod coal	3	0	0
19.	Clod coal	0	1	6
20.	To the flint coal	3	0	0
21.	Flint coal	0	2	3
		101	0	9

LANGLEY FIELD PITS.

1.	Soil	1	0	0
2.	Rock	16	0	0
3.	Clody parting	1	0	0
4.	Rock	5	0	0
5.	Bind rock and mingled ground	7	1	0
6.	Clunch	5	0	6
7.	Pimp rock and mingled ground	6	0	0
8.	Blue clod	10	0	0
9.	Chance coal	0	1	4
10.	Tator butt	1	1	0
11.	Brick measure	3	1	0
12.	Rock	8	0	0
13.	Clunch	4	1	6
14.	Binds	8	0	0
15.	Mingled ground	2	2	0
16.	Coal	0	2	3
17.	Rock	1	1	0
18.	Double coal	2	0	0
19.	Bunstone	0	1	6
20.	Rock	1	0	0
21.	Coal	1	0	0
22.	Breccia	3	0	0
23.	Clod	1	1	0
24.	Sparstone	2	0	0
25.	Coal	1	0	3
26.	Flint	11	0	0
27.	Penneystone measure	6	0	0
28.	Sulphur coal	1	0	0
29.	Over clunches	8	0	0
30.	Sill coal	0	1	0
31.	Clunch	0	1	0
32.	Coal	1	2	0
33.	Carbel	0	2	0
34.	Best coal	1	1	0
35.	Three coals	1	1	8
36.	Riliff	0	1	6
37.	Poundstone	1	0	0
38.	Rock	1	0	0
39.	Little flint	3	0	0
40.	Coal	0	2	0
41.	Lower flint	3	0	0
42.	Crawstone	0	2	10
		135	1	10

NEW HADLEY.

1.	Earth and clay	2	0	0
2.	Wild red ground	23	2	0
3.	Bibley rock	0	2	0

No.	Yds.	Ft.	In.
4. Strong red ground	5	2	0
5. Four-feet rock	1	1	6
6. Rock binds	0	2	0
7. Strong clunch	1	2	0
8. Penneystone rock	0	2	1
9. Chance penneystone	1	0	0
10. Clunch binds	0	3	0
11. Coal and bass	0	1	6
12. Fungous coal rock	9	0	0
13. Fungous coal	1	0	0
14. Poundstone and ragged robins	0	2	6
15. Foot coal	0	1	0
16. Clod	0	2	0
17. Blackstone measure	1	0	6
18. Clod and stone measure	1	1	6
19. Soft fire clay	0	1	0
20. Clod and gur coal	0	2	0
21. Grey rock	7	0	0
22. Brick-measure stone	1	0	6
23. Clunch	1	0	0
24. Bind	0	2	0
25. Bass	0	2	0
26. Bind rock	8	0	0
27. Ballstone	2	0	0
28. Dun earth	2	2	0
29. Top coal	1	1	6
30. Slums and three-quarter coal	0	2	6
31. Double coal rock	3	0	0
32. Double coal	1	0	0
33. Double coal bottoms	0	1	6
34. Poundstone	0	2	0
35. Yellow stone	0	2	6
36. Bass	0	1	0
37. Yard coal and bass	1	0	0
38. Clod	0	2	6
39. Pitcher bass	1	2	0
40. Eight-yard rock	8	0	0
41. Strong rock binds	4	2	0
42. Flint coal	1	2	0
43. Flint coal rock	6	0	0
44. Bottom penneystone	7	0	0
45. Sulphur coal	2	1	0
46. Gritty fire clay	2	0	0
47. Coal bass and coal	1	2	6
48. Clunch	2	1	0
49. Two feet coal	0	2	6
50. Clunch	1	2	0
51. Coal and bass	0	0	6
52. Clunch binds	2	0	6
53. Clod coal	1	0	0
54. White and blue clunch	7	0	0
55. Little flint coal	0	1	6
56. White rock	3	0	0
57. Crawstone fee (or measure,)	0	2	3
	142	2	4

HOLYWELL PITS, MALINSLEE.

1. Clay	1	2	0
2. Mingled measure, blue and red	10	1	0
3. Blue clod	15	0	0
4. Top rock	25	0	0
5. Blue clod	28	0	0
6. First sulphur rock	11	1	6
7. Coal	0	0	9
8. Fire clay	0	2	6
9. Coal	0	1	0
10. Clod	1	0	6
11. Second sulphur rock	17	2	9
12. Coal	0	0	9
13. Dark clod	0	2	0
14. Coal	0	0	9
15. Tator butt	2	1	0
16. Brickman's measure	0	2	6
17. Rough rock	2	2	0
18. Red and blue clod	7	1	0
19. White binds	1	2	0
20. Red clod	1	1	6
21. Mingled red and white clod	1	0	0
22. White bindy clod	1	1	0
23. White and yellow binds	3	0	0
24. Strong dark clod	1	0	6
25. Ditto binds	6	2	0
26. Brown tarred rock	4	0	6
27. Strong binds dark	1	2	0
28. Three quarters coal	0	1	0
29. Double coal rock	1	2	0
30. Double coal	2	0	3
31. Ditto Poundstone	0	1	6
32. Yellow stone fay (or measure)	1	1	0
33. Yard coal	1	0	0
34. Ditto Poundstone	0	1	6
35. Quoice neck	0	1	6
36. Blue flat fay	1	1	6
37. Pitcher basses	1	2	0
38. Blacks	0	2	0
39. White flat clod	2	2	0
40. Flint coal and bass	1	2	6
41. Flint	5	0	0
42. Penneystone clod	6	1	6
43. Sulphur coal	1	1	0
44. Upper clunches	6	0	6
45. Sill coal and bass between	0	2	6
46. Lower clunches	0	1	6
47. Two-foot coal	0	2	6
48. Linseed earth	0	1	4
49. Best coal	0	1	6
50. Randles and bass	1	0	4
51. Clod coal	0	2	4
	188	2	3

STURCHLEY COMMENCEMENT OF MEADOW PITS.

1. Sand and gravel	7	1	6
2. Light-coloured clod	9	2	0
3. Top-rock brown	3	1	6
4. Light-coloured clod	7	1	6
5. Sulphur rock	12	0	0
6. Bass and coal	0	1	0
7. Fire clay	0	1	8
8. Coal	0	1	0
9. Tator butt	1	1	0
10. Light blue clod	3	1	6
11. Red clod	1	1	6
12. Light blue clod, strong	1	2	6
13. Red clod	1	0	0
14. Strong white clod	9	0	0
15. Mingled clod	3	1	6
16. Coal	0	1	0
17. Dark kind clod	9	1	6
	72	2	8

DAWLEY PIT.

1. Gravel and soil	3	0	0
2. Top rock	3	1	6
3. Blue clod	3	1	6
4. Strong measure	1	0	0

No.		Thickness. yds.	ft.	in.
5.	Jointy rock	10	0	0
6.	White clod	2	2	3
7.	Red tough clod	4	0	0
8.	White clod, jointy	11	2	3
9.	Brown rock	6	1	6
10.	Sulphur coal	0	1	0
11.	Tough clod	1	0	6
12.	Laver coal	0	1	0
13.	White clod	2	2	3
14.	Brown clod	1	0	0
15.	White hard clod	3	2	3
16.	Red clod	1	0	9
17.	Blue pimply clod	5	0	0
18.	Mingled red clod	1	0	2
19.	Sulphur coal rock	7	0	0
20.	Hard strong clod	6	0	2
21.	Sulphur coal	1	0	0
22.	Clod	1	0	0
23.	Cover coal	0	1	6
24.	Blue clod	2	1	6
25.	Red clod	4	0	2
26.	Rough rock	6	0	2
27.	Yellow stone earth	6	0	0
28.	White cutting rock	7	0	0
29.	Stone clod	2	0	0
30.	Top coal	1	1	0
31.	Slums and double coal	2	0	2
32.	Heathen earth	3	0	0
33.	Dun Bass	0	2	3
34.	Yard coal	1	0	0
35.	Quoice neck	0	2	3
36.	Basses and two coal	3	0	0
37.	Clod	2	0	0
38.	Flint coal	1	0	2
39.	Upper flint	6	0	0
40.	Penney measure ironstone	5	0	0
41.	Sulphur coal	1	0	0
42.	Clod	0	1	0
43.	Lower coal	0	0	6
44.	Upper clunches	5	1	6
45.	Sill coal	0	1	6
46.	Lower clunches	5	0	2
47.	Soft clod	0	1	6
48.	Lower sill coal	0	1	6
49.	Two foot rock and coal	1	0	0
50.	Linseed earth	0	1	0
51.	Best and middle coal	1	0	2
52.	Clod	1	1	6
53.	Clod coal	1	0	0
54.	Clod	2	0	0
55.	Flint coal	1	0	0
		153	0	1

STRATA OF THE OLD PARK PITS.

1.	Brick clay	2	0	0
2.	Top rock	3	1	6
3.	Clod	14	1	6
4.	Short earth, with ironstone	2	1	0
5.	Chance-stone fey	2	0	0
6.	Rock	1	1	0
7.	Ball-stone	3	0	0
8.	Bass	0	1	0
9.	Top coal	1	1	6
10.	Top coal poundstone	7	0	0
11.	Double coal	2	0	0
12.	Yellow stone	1	1	0
13.	Yard coal	1	0	0
14.	Quoiceneck	0	1	0
15.	Blue flat	1	2	0
16.	Pitchy Bass	0	1	6
17.	White flat	3	0	0
18.	Bass	0	1	6
19.	Flint coal	1	1	6
20.	Flint	5	0	0
21.	Penneystone	7	0	0
22.	Sulphur coal	1	1	0
23.	Clunch	5	0	0
24.	Linseed earth	0	1	6
25.	Two foot coal	0	2	0
26.	Clunch	0	1	0
27.	Randle coal	1	0	0
28.	Hard spire	0	0	6
29.	Clod coal	0	2	4
30.	Clod coal poundstone	1	1	0
31.	Rock	5	0	0
32.	Little flint	0	1	8
	Little flint rock, unknown, said to be very hard and black.	78	9	5

TUB ENGINE PIT, BY THE FIRE-ENGINE IN DONNINGTON WOOD.

Names of the Coals and Ironstones.	Quality.	Thickness of the Strata. yds.	ft.	in.	Thickness between the Strata. yds.	ft.	in.
Donnington Wood coal	Very good coal	1	0	4	27	1	11*
Black stone	Very good stone	1	0	0	4	0	0
Stone coal	Indifferent coal	1	0	0	2	1	9
Gur coal	Indifferent coal	0	2	3	0	2	0
White ball-stone	Very good stone	1	0	0	23	2	0
Top coal	Very good coal	1	1	6	0	2	9
Double coal	Good coal	2	0	0	2	2	3
Yellow stone	Good stone	0	2	6	3	0	0
Yard coal	Ordinary coal	1	0	0	0	1	6
Blue flat stone	Good stone	1	0	0	0	2	0
Big flint coal	Good coal	1	1	6	10	0	0
Penneystone	Not very good	1	0	0	7	0	0
Sulphur coal	Bad coal	1	0	0	8	0	0
Sill coal	Good coal	0	1	8	5	0	0
Two-feet coal	Good coal	0	2	0	3	0	0
Randle coal	Good smiths' coal	1	0	6	3	0	0
Clod coal	Good furnace coal	1	0	0	1	0	0
Little flint coal	Very good coal	0	2	3	4	0	0
		18	2	6	117	1	4
					18	2	6
	Depth of the pit				136	0	10

* Distance from the surface to the first coal.

MEADOW PITS. MADELEY.

Two Shafts, a few yards (12?) apart.

No.	Basset Pit. yds.	ft.	in.	Deep Pit. yds.	ft.	in.
1. Soil	1	2	3	1	2	0
2. Soft gritty earth	7	1	2	7	1	10
3. Yellow clunch	0	2	11	0	2	6
4. Blue clunch	0	2	2	0	2	11
5. Blue and white clunch	1	1	2	2	1	0
6. Light rock, very hard	3	1	8	4	1	1
7. Dark brown and blue clunch	2	0	4	1	2	8
8. Light blue clunch	3	2	2	3	1	2
9. Light rock	2	1	6	2	0	5
10. A very hard stone	0	0	9	0	0	10
11. Dark brown and blue clunch	3	1	0	4	0	3
12. Blue clod	2	2	8	3	1	0
13. Light rock	3	2	0	3	2	0
14. Dark rock	1	2	4	1	2	0
15. Sulphur coal	0	0	4	0	0	4
16. Blue and red clunch	3	1	2	3	1	0
17. Blue gritty rock	2	2	1	2	2	0
18. Dark clod	4	1	10	4	2	6
19. Light rock	3	2	7	3	1	0
20. Sulphur coal	0	0	6	0	0	6
21. Brown and blue clunch	2	1	4	2	2	0
22. Dark clunch	3	1	0	3	1	8
23. Dark rock	1	2	3	0	2	0
24. Very dark rock	3	1	9	3	2	1
25. Red, blue, and yellow clunch	2	2	8	3	1	0
26. Sulphur coal	0	0	4	0	0	4
27. Dark red and blue clunch	4	1	0	4	0	8
28. Light blue rock	3	2	1	3	2	4
29. Red clod	5	1	10	5	2	0
30. Sulphur coal	0	0	5	0	0	5
31. Light rock	4	0	2	4	1	0
32. Dark blue and brown rock	0	1	11	0	2	2
33. Blue cloddy parting	0	0	7	0	0	7
34. Brown and blue rock	0	2	10	0	2	11
35. Light blue clod	4	0	9	3	0	10
36. Sulphur coal	0	0	4	0	0	4
37. Pricking	0	0	2	0	0	2
38. Sulphur coal	0	0	7	0	0	7
39. Dark coloured clod	0	2	10	1	0	1
40. Sulphur coal	0	0	10	0	0	10
41. Brown and blue clunch	1	1	3	1	1	6
42. Dark pebbly rock	2	2	6	2	2	0
43. Blue cloddy parting	1	1	0	1	1	3
44. Dark pebbly rock	2	1	0	2	2	0
45. Dark coloured rock	6	0	0	5	1	10
46. Red clunchy parting	0	2	8	1	0	2
47. Light coloured rock	3	2	10	4	0	6
48. Dark coloured rock	5	1	0	5	2	1
49. Yellow and blue clunch	3	2	6	3	2	9
50. Dark brown rock	6	0	10	6	1	0
51. Dark clunch	5	2	4	4	1	5
52. Sulphur coal	0	0	6	0	0	6
53. Dark clod	0	1	2	0	1	2
54. Sulphur coal	0	0	8	0	0	8
55. Dark clod	1	1	0	1	1	6
56. Main sulphur coal	0	1	8	0	1	8
57. Pricking under sulphur coal	0	0	4	0	0	4
58. Dark strong clunch	1	0	2	1	0	6
59. Dark rock	1	1	0	1	1	6
60. Brown and blue clunch	1	0	0	1	0	4
61. Blue and brown rock	2	1	3	2	2	0
62. Light blue and brown rock	1	0	2	1	0	0
63. Red and yellow clunchy parting	0	1	0	0	1	6
64. Crudley blue and brown rock	2	0	2	2	0	2
65. Dark rock, very hard	1	0	4	1	0	6
66. Dark rock, full of pebbles	0	1	6	0	1	4
67. Light rock, full of pebbles, green, blue, and red—hard	4	1	8	3	2	6
68. Light rock	2	1	0	2	2	0
69. Dark rock, very hard	1	0	10	1	0	0
70. Light blue rock	2	1	0	2	2	0
71. Blue rock	5	1	4	5	0	6
72. Dark shining clod	1	2	0	1	2	6
73. Top of the rider coal	0	0	6	0	2	4
74. Rider coal	1	1	0	1	0	2
75. Strong dark clod	0	0	3	0	0	3
76. Bottom of rider coal	0	0	9	0	0	9
77. Pricking under rider coal	0	0	8	0	0	8
78. Dark clunch	1	0	5	1	0	7
79. Heaving earth	1	1	0	1	1	0
80. Dark clod, and large iron-stone	20	1	0	20	0	6
81. Lessoms of coal and slum	0	2	10	0	2	6
82. Dark clunch	1	0	6	1	0	10
83. The blacks	1	1	6	1	1	4
84. Sill coal	0	0	10	0	0	10
85. The bass	1	0	2	1	0	2
86. Bottom coal	1	0	0	1	0	0
87. Bottom coal, flint, or big flint; upper and middle part of the flints	4	1	4	4	1	0
88. Very hard brown stone	0	0	9	0	0	9
89. Lower part or bottom of the flint	1	0	5	1	0	5
90. Penney measure ironstone	1	2	1	1	2	4
91. Pricking under penneystone	0	0	5	0	0	4
92. Clod under penneystone	0	1	1	0	1	2
93. Sulphur coal	0	1	4	0	1	4
94. Viger coal rock	3	1	2	3	1	0
95. Viger coal	0	1	3	0	1	4
96. Upper part of the two-foot rock, clunchy	0	2	4	0	2	11
97. Middle part of the rock, very large balls of iron-stone line this rock	3	1	4	3	2	5
98. Bottom of the two-foot rock clunchy	2	1	0	1	2	7
99. Dark clod upon two-foot coal	0	0	9	0	0	9
100. Two-foot coal, very indifferent	0	1	3	0	1	4
101. Pricking under two-foot coal	0	0	8	0	0	9
102. Upper part of the Ganey coal	1	2	2	1	1	1
103. Little Ganey coal	0	0	6	0	0	6
104. Lower part of Ganey coal	2	0	2	2	0	8
105. Ganey coal-stone	0	0	6	0	0	6
106. Main Ganey coal	0	1	3	0	1	3
107. Pricking under main Ganey coal	0	0	6	0	0	6
108. Upper part of the best coal rock	5	2	0	5	2	8
109. Clod on the top of the best coal	0	0	7	0	1	4
110. Best coal	0	2	8	0	2	8
111. Clod, very soft	0	1	8	0	1	6
112. Clod, very hard	0	2	10	0	2	6
113. Middle coal, very indifferent	0	2	8	0	2	8
114. Clod between middle and clod coal	0	0	10	0	0	9
115. Clod coal, very good	0	1	10	0	1	10

No.		Basset Pit. yds.	ft.	in.	Deep Pit. yds.	ft.	in.
116.	Pricking under clod coal	0	0	7	0	0	7
117.	Clod coal, clunch, or Pound-stone	0	2	1	0	2	8
118.	Little flint-coal, Tuff very hard, and full of large ironstone	4	1	10	3	0	1
119.	Strong rock	0	0	0	0	2	0
120.	Clod upon the flint coal	0	0	0	0	1	4
121.	Little flint coal	1	0	4	1	0	3
122.	Little flint coal, flint	0	1	2	1	0	0
123.	Crawstone measure — Left off sinking in this shaft				0	1	3
124.	Crawstone — Left off sinking in this shaft						
125.	Coal to hole under Crawstone				0	0	6
126.	Top of the Crawstone flint				0	2	0
127.	Crawstone flint, light coloured, and very hard				0	1	8
128.	Do. do., not very hard				1	1	8
129.	A very hard stone				0	1	4
130.	Dark coloured, full of small pebbles				0	1	0
131.	Bottom of the flint				1	1	10
132.	Lancashire ladies' coal				0	0	8
133.	Top of the dye earth light coloured — Upper Ludlow Rock				2	2	6
134.	Do. blue coloured — Upper Ludlow Rock				0	1	0
		233	2	8	244	2	9

HILL'S LANE PITS. MADELEY.

(Description of the beds from an examination of Specimens in the possession of W. Anstice, Esq., F.G.S.)

These two Shafts are only about 10 yards apart.

No.	Local Names.	Description of the Beds.	Deep Pit. yds.	ft.	in.	Basset Pit. yds.	ft.	in.
1.	Soil, sand, and gravel	Soil and diluvium	3	1	6	2	1	0
2.	Clay, mingled red and yellow	Mottled clay	1	0	6	2	1	3
3.	Small sulphur coal	Fibrous coal, full of iron pyrites	0	0	0	0	0	3
4.	Dark clod parting	Light grey clay	0	2	0	0	1	6
5.	Sulphur coal	Fibrous coal, full of iron pyrites	0	0	6	0	0	6
6.	Blue clod	Bluish grey shale	6	1	0	6	2	0
7.	Brown clod	Dark brownish grey shale	2	2	3	2	2	6
8.	Blue clod	Dark grey shale	1	1	6	2	0	6
9.	Blue rock	Hard, bluish, grey, calcareous sandstone, slightly crystalline	10	2	2	9	2	6
10.	Blue clod	Hard, dark grey shale	0	0	9	0	1	0
11.	Red clay	Red clay	0	1	0	0	1	6
12.	Blue clunch	Greenish indurated clay	3	0	0	3	0	0
13.	Red clay	Red clay	2	1	0	2	1	3
14.	Mingled red and blue	Mottled clay	2	1	6	2	1	0
15.	Blue clod	Greenish shale	9	1	2	9	1	2
16.	Brown parting	Dark grey marl	0	0	6	0	0	8
17.	Blue clod	Greenish shale	1	2	6	1	1	9
18.	Blue rock	Light blue, calcareous sandstone, soft and fine-grained	0	2	10	0	2	10
19.	Clod, mingled blue and yellow	Mottled clay	1	0	0	1	0	0
20.	Dark parting	Dark grey coaly clay	0	0	6	0	0	4
21.	Clod, mingled blue and brown	Mottled marl	2	1	6	2	1	10
22.	Blue clod	Light grey shale	2	1	6	2	1	0
23.	Brown and blue clod	Mottled shale	0	1	8	0	1	0
24.	Rock	Light brown, slightly calcareous sandstone	0	1	0	0	1	0
25.	Blue clod	Light greenish shale	0	1	6	0	1	0
26.	Blue rock	Compact, light blue marl	0	2	0	0	1	9
27.	Blue clod	Grey shale	2	0	0	1	2	3
28.	Mingled blue and red	Dark mottled clay	0	2	6	1	0	6
29.	Blue clod	Light grey shale	1	1	0	0	2	3
30.	Rocky bind	Grey sandstone, very argillaceous	9	2	6	9	0	0
31.	Brown clod	Dark brown shale, with a few ironstone nodules	0	2	0	0	2	0
32.	Blue bind	Greyish slate clay	9	0	0	8	1	0
33.	Sulphur coal	Fibrous coal, with iron pyrites	0	0	3	0	0	6
34.	Dark clunch	Dark grey clay	2	1	3	2	2	9
35.	Blue clod	Very hard grey shale	4	0	0	3	2	8
36.	Sulphur coal	Foliated, pyritous coal	0	0	9	0	0	9
37.	Dark clunch	Very hard grey clay	2	0	9	2	0	8
38.	Sulphur coal	Fibrous coal, very pyritous	0	0	4	0	0	4
39.	Dark clay	Mottled grey and brown indurated clay	0	2	6	0	2	0
40.	Blue rock	Mottled grey and brown calcareous breccia	2	2	6	3	1	0

No.	Local Names.	Description of the Beds.	Deep Pit. yds.	ft.	in.	Basset Pit. yds.	ft.	in.
41.	Blue clod	Very hard greyish shale	1	0	10	1	2	0
42.	Blue and brown clod	Mottled marl	2	2	8	2	1	0
43.	Blue rock	Light green and fine slightly argillaceous sandstone	4	2	0	4	1	0
44.	Blue and brown clod	Dark mottled marl	1	2	6	2	1	4
45.	Dark clod	Dark grey shale	1	0	6	0	1	6
46.	Sulphur coal	Fibrous coal, slightly pyritous	0	0	5	0	0	0
47.	Blue clod	Dark grey marl	2	2	8	3	0	4
48.	Sulphur rock	Light brown, coarse, argillaceous sandstone, highly charged with petroleum	12	0	2	11	2	10
49.	Sulphur coal	Foliated coal, slightly pyritic	0	0	10	0	1	0
50.	Dark clunch	Indurated clay	1	1	2	1	1	0
51.	Rock light	Fine slightly argillaceous and micaceous sandstone	4	2	0	4	1	6
52.	Red clay	Dark red clay	2	0	8	2	0	2
53.	Ball rock	Mottled grey and brown calcareous breccia	2	0	0	2	0	0
54.	Red clay	Dark red clay	0	1	8	0	1	10
55.	Light blue rock	Light green, compact argillaceous sandstone	4	1	9	5	0	2
56.	Light blue binds	Light green marl	2	2	0	2	2	3
57.	Blue and brown clod	Mottled shale	2	1	2	2	1	0
58.	Light rock	Calcareo-argillaceous sandstone	0	2	6	1	0	0
59.	Dark cloddy parting with mine	Shale, containing a few nodules of ironstone (mine)	0	1	11	0	1	5
60.	Dark rocky bind	Hard, dark, calcareous, and argillaceous sandstone	8	1	4	8	2	0
61.	Small sulphur coal	Fibrous coal, full of iron pyrites	0	0	4	0	0	4
62.	Dark clod	Marl	0	1	8	0	2	7
63.	Sulphur coal (main)	Foliated, pyritous coal	0	2	0	0	2	0
64.	Light bind	Marl	2	0	0	2	0	2
65.	Blue and brown clod	Mottled shale, very siliceous	4	1	10	3	0	0
66.	Brickman's clay (red)	Indurated red clay	0	0	0	1	1	0
67.	Rough rock	Coarseish quartzose conglomerate, with a calcareous cement	8	1	3	9	0	6
68.	Red clay	Indurated red clay	0	2	6	3	1	0
69.	Blue and brown bind	Very fine, slightly micaceous and argillaceous sandstone	1	1	0	1	2	0
70.	Rock	Coarse sandstone, highly charged with petroleum	9	0	6	9	1	6
71.	Mingled red and brown, with dark parting mine	Mottled shale, containing a few nodules of ironstone	2	2	0	8	0	10
72.	Very hard rock	Brown, hard, rather coarse sandstone, with small calcareous concretions, highly impregnated with petroleum	2	0	6	0	0	0
73.	Mingled red and blue clod	Shale, with petroleum	2	2	0	0	0	0
74.	Blue and brown bind	Hard, argillaceous, mottled sandstone, highly impregnated with petroleum	2	1	0	0	0	0
75.	Dark clod, with mine	Carbonaceous shale, with little petroleum, and a few iron-stone nodules	1	1	0	0	0	0
76.	Bottom coal flint	Fine-grained, white sandstone, with a few patches of petroleum	6	1	4	6	1	0
77.	Penneystone measure	Dark grey shale, containing numerons small, flattish ironstone nodules	1	1	0	1	1	0
78.	Sulphur coal	Cherry coal, containing iron pyrites	0	1	3	0	1	0
79.	Viger coal rock	Fine grey slightly argillaceous sandstone	5	1	0	5	0	10
80.	Viger coal	Foliated coal	0	1	8	0	1	6
81.	Dark clunch	Indurated clay	0	2	6	0	2	6
82.	Two-foot rock	Dark grey, compact marl	5	2	3	5	2	0
83.	Dark clod	Shale	0	0	9	0	0	6
84.	Two-foot coal	Foliated coal	0	1	8	0	1	6
85.	Ganey coal clunch	Dark grey indurated clay	2	1	9	2	2	0
86.	Little Ganey coal	Fibrous coal, slightly pyritous	0	0	7	0	0	6
87.	Little Ganey coal clunch	Sandy clay, with oxide of iron	2	0	0	2	0	0
88.	Lower Ganey rock	The same, rather harder, and charged with petroleum	0	0	5	0	0	4
89.	Lower Ganey coal	Foliated coal	0	1	6	0	1	6
90.	Clunch	Dark, indurated clay	0	2	8	0	2	0
91.	Best coal	Slate-coal	0	2	5	0	2	8
92.	Basses	Hard, bituminous shale	0	0	7	0	0	6
93.	Randle coal	Slate-coal	0	2	8	0	2	4
94.	Clunch	Dark, indurated clay	0	1	0	0	0	9
95.	Clod coal	Slate-coal	0	1	4	0	1	2
96.	Clod coal clunch	Dark, indurated clay	1	1	0	1	0	4
97.	Clod, with ironstone	Hard, dark shale, with large nodules of ironstone	0	2	6	0	2	3
98.	Hard rock	Bituminous slate clay	0	0	4	0	0	4

No.	Local Names.	Description of the Beds.	Deep Pit. yds.	ft.	in.	Basset Pit. yds.	ft.	in.
99.	Little flint coal	Slate-coal	0	0	4	0	0	4
100.	Rock in the coal	Fine hard white sandstone, slightly micaceous	1	2	3	1	2	0
101.	Lower little flint-coal	Slate-coal	0	2	6	0	2	3
102.	Little flint	Hard, fine, white sandstone	1	2	6	2	1	0
103.	Crawstone measure	Hard, fine sandstone, light brown, slightly micaceous and bituminous	1	0	0	2	0	6
104.	Coal under ditto	Slate-coal	0	1	0	0	0	10
105.	Crawstone crust	Whitish, fine, rather friable sandstone	1	2	7	1	2	3
106.	Lancashire ladies' coal	Fibrous coal	0	0	9	0	0	9
107.	Rock, very hard	White, compact sandstone, containing numerous quartzy pebbles	0	2	0	0	1	0
108.	Ditto	Compact, white, argillaceous sandstone, slightly oolitic	1	0	0	1	1	6
			231	0	1	230	1	11

The last stratum immediately overlies the Wenlock Limestone at Lincoln Hill.

MINERALS OF THE COAL MEASURES. (B.)

ARRAGONITE ..... Occurs with barytes, but rarely.

BARYTES, crystallised ..... Beautiful crystals occur in the large nodules of ironstone from the bituminous shale overlying the little flint coal in Broseley and Caughley parishes.

CHARCOAL, mineral ..... Common in the fungous and some of the upper coals, forming thin laminæ alternating with others of the crystalline coal:—also in the sulphur coal of Kingslow, where it is frequently iridescent from its admixture with iron pyrites.—A few fragments of very pure mineral charcoal have been found in some of the Penneystone nodules.

IRON, carbonate, crystallised ..... In the nodules of ironstone—principally the white flatstone and Penneystone.

argillaceous ..... Forms the nodules of the ironstone measure.

earthy red ochre ..... Occasionally forms nodules in some of the sandstones.

peroxide ..... Dispersed in small quantities throughout most of the strata.—Compact hematitic masses occur in the large ironstone nodules of the little flint coal shale.

phosphate ..... Rare.—In the Penneystone nodules.

sulphuret, common iron pyrites ..... } Very abundant in some of the coal beds—called sulphur coals.

arsenical ..... Cryslets in ironstone nodules, and coal beds,—rather rare. Sometimes the arsenic volatilizes, and can be collected from the blast furnaces.

hexahedral ..... In ironstone nodules.—In detached masses in the interior of the Penneystone nodules.

octohedral ..... Ditto. ditto.

rhombohedral ... Ditto. ditto.

radiated ..... Ditto. ditto.

LEAD, sulphuret, Galena ..... Rare.—In the Penneystone nodules.

LIME, carbonate, crystalline ..... In veins in the coal and in ironstone nodules.

crystallised ..... Beautiful tetrahedral crystals occur with the fragments of brown wood in the Penneystone nodules at Madeley, also rhomboidal and tetrahedral crystals in the curlstone at Woombridge.

PETROLEUM, viscid ..... Occasionally in cavities in Penneystone nodules; the white flats, crawstone, &c.—It is also commonly diffused throughout the central coal series, and in the flint coal and roof at Caughley.

PHOLERITE, of Guillemin. ..... Of frequent occurrence in crevices of the ironstone nodules, especially the Penneystone, in the casts of plants in ironstone, &c.

TITANIUM ..... Is not of rare occurrence in the hearthstone of the iron blast furnaces, where it is found both massive and in brilliant cubic crystals; it exists naturally apparently as titanic acid combined with iron and zinc.

ZINC, sulphuret, Blende ..... Common in almost all the ironstones,—frequently forms the casts of plants.—Beautiful dodecahedral crystals occur in detached masses in the interior of the Penneystone nodules, and in the casts of shells.

cadiniferous ..... Occurs in the Penneystone nodules and the white flats, but rarely.

SYSTEMATIC LIST OF FOSSILS (C).†

PLANTÆ. Genus, Species and Reference.	FORMATION. COAL AND PARTICULAR BEDS.
Calamites.	
cannæformis, Schlotheim, t. 20. t. 15. f. 1.	The first two species are common in all the lower strata, especially in the flint-coal sandstone overlying the Penneystone at Ketley, and occur chiefly in the white and blue flat measures.
arenaceus Jæger, see Ad. Brong., i. p. 138. t. 25. f. 1. t. 26. f. 3–5.	
approximatus, (Sternb.) Ad. Brong., i. p. 133. t. 24.	
nodosus, Schlotheim, t. 20. f. 3.	
Cyclopteris.	
obliqua, Ad. Brong., i. p. 221. t. 61. f. 3.	Ballstone. Rare.
oblata, L. and H., iii. t. 217	Ibid.
orbicularis, Ad. Brong., i. p. 220. t. 61. f. 1, 2.	Ibid.
semiflabelliformis, n. s., Pl. XXXVIII.‡ fig. 7	Ibid.
Neuropteris.	
ingens, L. and H., ii. t. 91 A.	Ballstone, and almost all the lower shales. Common.
gigantea, (Sternb.) Ad. Brong., i. t. 69.	Ibid.
Loshii, Ad. Brong., i. p. 242. t. 72. f. 1.	Ibid.
Sorettii, Ad. Brong., i. p. 244. t. 70. f. 2	Ibid.
Odontopteris.	
obtusa, Ad. Brong., i. p. 255. t. 78. f. 3, 4.	Ballstone. Rare.
Pecopteris.	
adiantoides, L. and H., i. t. 37	Ballstone, white flat, and most of the lower shales. Common.
abbreviata, Ad. Brong., i. p. 337. t. 115. f. 1–4.	Ibid.
heterophylla, L. and H., t. 38.	Ibid.
lonchitica, Ad. Brong., i. p. 275. t. 84. f. 1–7. t. 128.	Ibid.
oreopteridius, Ad. Brong., i. p. 317. t. 104. f. 1, 2.	Ibid.
muricata, Ad. Brong., p. 352. t. 95. f. 3, 4. t. 97.	Ibid.
nervosa, Ad. Brong., i. p. 297. t. 94.	Ibid.
Sphenopteris.	
Conwayi, L. and H., ii. t. 146	Ballstone, and the best clod coal rocks. Common.
dilatata, L. and H., i. t. 47.	Ibid.
latifolia, Ad. Brong., i. p. 205. t. 57. f. 1–5	Ibid.
macilenta, L. and H., ii. t. 151.	Ibid.
multifida, L. and H., ii. t. 123.	Ibid.
obtusiloba, Ad. Brong., i. p. 204. t. 53. f. 2.	Ibid.
polyphylla, L. and H., ii. t. 147.	Ibid.
Lepidodendron.	
acerosum, L. and H., i. t. 7. f. 1. t. 8.	
aculeatum, Sternb., t. 7. f. 1. t. 8. f. 1 B.	Ballstone, and white and blue flat. Common.
elegans, (Ad. Brong., Prod. 35.) L. and H., ii. t. 118.	Ibid.
dilatatum, L. and H., i. t. 7. f. 2.	Ibid.
gracile, L. and H., i. t. 9.	Ibid.
Harcourtii (Witham), L. and H., ii. t. 98, 99.	Ballstone.
obovatum, Sternb., pt. 1. p. 21. t. 6. f. 1. t. 8. f. 1 *a*.	Ballstone, and white and blue flat. Common.
ornatissimum, Ad. Brong., ii. t. 18.	
Sternbergii, (Ad. B. Prod. 85.) L. and H., i. t. 4. ii. t. 112. 203	Ibid.
selaginoides, Sternb., pt. 1. p. 35. t. 16. f. 3. t. 17. f. 1.	Ibid.
rimosum, Sternb., t. 10. f. 1.	Flint coal, sandstone.
Lycopodites?	
longibracteatus, n. s., Pl. XXXVIII. fig. 9, 10, 11.	Best coal rock. Very rare, except at Broseley.
Lepidostrobus.	
ornatus, (Ad. Brong.), L. and H., i. t. 26.	Ballstone, and white flat.
variabilis, L. and H., i. t. 10. and 11.	Ibid., and blue flat.

† I beg to acknowledge the assistance which Mr. Morris has afforded me in the examination of my collection of coal-measures plants, and in describing the new species.

‡ The numerals refer to the Plates which illustrate the Memoir.

PLANTÆ. Genus, Species and Reference.	FORMATION. COAL AND PARTICULAR BEDS.
MEGAPHYTUM.	
approximatum, L. and H., ii. t. 116	Ballstone. Rare.
HALONIA.	
tortuosa, L. and H., iii. t. 85.	Flint coal sandstone.
disticha, n. s., Pl. XXXVIII. fig. 1	Ibid.
KNORRIA.	
Taxina, L. and H., ii. t. 95. Pl. XXXVIII. fig. 6	Ballstone. Rare.
imbricata, Sternb., t. 27	Ibid. Ibid.
SIGILLARIA.	
Murchisoni, L. and H., ii. t. 149	Lower series, best coal rock. Common.
oculata, L. and H., i. t. 59.	Ibid.
organum, L. and H., i. t. 70	Ibid.
reniformis, Ad. Brong., An. des Sc. Nat., iv. p. 32. t. 2. f. 2	Ibid.
FAVULARIA.	
tesselata, L. and H., i. t. 73–75.	Lower series. Rare.
BOTHRODENDRON.	
punctatum, L. and H., t. 80, 81. and 218.	Flint coal sandstone.
POACITES.	
cocoina, L. and H., ii. t. 142 B	Flint coal. Very rare.
TRIGONOCARPUM.	
ovatum, L. and H., ii. t. 142 A.	Ballstone? Very rare.
Dawesi? L. and H., t. 221.	Ibid.
PALMACITES.	
astrocariiformis, Sternb., t. 8. f. 23	Ballstone. Very rare.
CARPOLITES.	
zamioides, n. s., Pl. XXXVIII. fig. 4.	Flint coal sandstone. Rare.
Helicteroides, n. s., Pl. XXXVIII. fig. 12	Ballstone. Rare.
ALNITES.	
Kefersteinii, Göpp. Act. Ac. Nat. Cur. xviii. t. 41. f. 5.	Ballstone and white flat.
ANTHOLITES.	
Pitcairniæ, L. and H., ii. t. 82	White flat and ballstone. Rare.
anomalus, n. s., Pl. XXXVIII. fig. 5, 6.	Ibid.
STIGMARIA.	
ficoides, (Ad. Brong., L. and H., i. t. 31–36.) Pl. XXXVIII. f. 3, 3*a* to 3*c*	Crawstone, flint-coal and flint sandstone. Very common.
melocactoides, Sternb., p. 38	Flint coal sandstone.
FLABELLARIA.	
Borassifolia, Sternb., pt. 2. t. 18.	Ballstone and best coal rock.
ASTEROPHYLLITES.	
foliosa, L. and H., i. t. 25. f. 1	Ballstone and white flat.
jubata, L. and H., ii. t. 133.	Ibid.
comosa, L. and H., ii. t. 108.	Ibid.
equisetiformis, L. and H., ii. t. 124	Ibid.
BRUCKMANNIA.	
tuberculata, Sternb., pt. 2. t. 45. f. 2.	Ballstone and white flat.
rigida, Sternb., t. 19. f. 1.	Ibid.
STERNBERGIA.	
approximata, (Ad. B. Prod., p. 137.) L. and H., t. 224 and 225	Flint coal sandstone.
BECHERA.	
grandis, Sternb., pt. 2. t. 49. f. 1	Ballstone. Rare.
charæformis, Sternb., t. 55. f. 3–5. Pl. XXXVIII. f. 2.	Ibid. Rare.
CYCLOCLADIA.	
major? L. and H., t. 130	Ballstone. Rare.
ENDOGENITES.	
striata, L. and H., t. 227. fig. *a*.	Lower sandstones.
Coniferous wood	Small worn fragments in the Penneystone—a large stem showing structure similar to the Pinites Withami in the flint coal.

(C).

SYSTEMATIC LIST OF FOSSILS (continued).

Genus, Species and Reference.	Plate and Figure. The numerals refer to the Plates which illustrate the memoir.	Formations. Coal Measures. Pennsylvanian.	White Flat.	Blue flat.	Carboniferous Limestone.	Old Red Sandstone.	Upper Ludlow.	Aymestry Limestone.	Lower Ludlow.	Wenlock Limestone.	Wenlock Shale.	Caradoc Sandstone.
POLYPARIA.												
Limaria clathrata, *Stein.* Mem. Soc. Geol. France, t. i.	20 *bis*, f. 6.	...	...	...	..	...	...	...	...	*	...	...
Cystiphyllum cylindricum, Silur. Syst.	16. f. 3.	...	...	...	...	...	...	...	...	*	...	...
Cyaphophyllum dianthus, *Goldf.*	15. f. 13.	...	...	...	...	...	...	...	...	*	...	...
——— turbinatum, *Goldf.*	16. f. 8.	...	...	...	...	...	...	...	...	*	*	...
——— ———		...	...	...	*	...	...	...	...	...	...	...
Acervularia Baltica, *Schweig. Beobach*, VI. Silur. S.	16. f. 8.	...	...	...	...	...	...	...	...	*	...	...
Astrea ananas, Silur. Syst.	16. f. 6.	...	...	...	...	...	...	...	...	*	...	...
Monticularia conferta, Silur. Syst.	16. f. 5.	...	...	...	...	...	...	...	...	*	...	...
Porites pyriformis, *Ehrenberg*, Silur. Syst.	16. f. 2.	...	...	...	...	...	...	...	...	*	...	...
——— tubulata, Silur. Syst.	16. f. 3.	...	...	...	...	...	...	...	...	*	...	...
Catenipora escharoides, *Lamark.* Anim. sans Vert. tom. ii. Silur. Syst.	15 *bis*, f. 14.	...	...	...	...	...	...	...	...	*	...	...
Syringopora ramulosa, *Goldf.*	25. f. 7.	...	...	...	*	...	...	...	...	...	...	...
Lithodendron sex-decimale, *Phillips*, Geol. York.	2. f. 11-13.	...	...	...	*	...	...	...	...	...	...	...
——— sociale, *Phillips*, Ibid.	2. f. 9, 10.	...	...	...	*	...	...	...	...	...	...	...
Lithostrotion floriforme, *Fleming*, *Martin* Derb.	43, 44.	...	...	...	*	...	...	...	...	...	...	...
Favosites Gothlandica, *Goldf.*	26. f. 3, 4.	...	...	...	...	...	...	...	...	*	...	...
——— alveolaris, (*De Blainv.*) *Goldfuss*	26. f. 1.	...	...	...	...	...	...	...	...	*	...	...
——— spongites, *Goldf.*	28. f. 1.	...	...	...	...	...	...	...	...	*	...	...
——— ? septosus, *Fleming* Brit. Anim., p. 529.		...	...	...	*	...	...	...	...	...	...	...
Stromatopora concentrica, *Goldf.*	8. f. 5.	...	...	...	...	...	...	...	...	*	...	...
Millepora repens, *Hisinger* Leth. Suecica.	29. f. 5.	...	...	...	...	...	...	...	...	*	...	...
Eschara ? scapellum, Silur. Syst.	15. f. 25.	...	...	...	...	...	...	...	...	*	...	...
Discopora squamata ? Silur. Syst.	15. f. 23.	...	...	...	...	...	...	...	...	*	...	...
Fenestella prisca, Silur. Syst.	15. f. 18.	...	...	...	...	...	...	...	...	*	...	...
Glauconome disticha, *Goldf.*	64. f. 15.	...	...	...	...	...	...	...	...	*	...	...
Aulopora tubæformis, *Goldf.*	29. f. 2.	...	...	...	...	...	...	...	...	*	...	...
——— ———		...	...	...	...	...	...	...	...	...	*	...
CRINOIDEA.												
Actinocrinites moniliformis ? *Miller*, Nat. Hist. Crinoid., p. 115.		...	...	...	...	...	...	...	...	*	...	...
——— ? expansus, *Phillips*, Silur. Syst.	17. f. 9.	...	...	...	...	...	...	...	...	*	...	...
Cyathocrinites goniadactylus, *Phillips*, Silur. Syst.	17. f. 1.	...	...	...	...	...	...	...	...	*	...	...
——— tuberculatus, *Miller*, Nat. Hist. Crinoid., p. 88.		...	...	...	...	...	...	...	...	*	...	...
——— rugosus, *Miller*, p. 89.		...	...	...	...	...	...	...	...	*	...	...
——— quinquangularis, *Miller*, p. 92.		*	...	...	...	...	...	...	...	...	...	...
Marsupiocrinites cælatus, *Phillips*, Silur. Syst.	18. f. 3.	...	...	...	...	...	...	...	...	*	...	...
INSECTA.												
Curculloides Ansticii, *Buckland*, Bridgew. T.	66″. f. 1.	*	...	...	...	...	...	...	...	...	...	...
——— Prestvicii, *Buckland*, Bridgew. T.†	66″. f. 2.	*	...	...	...	...	...	...	...	...	...	...

† Mr. Mantell has discovered, in an ironstone nodule from Coalbrook Dale, the wing of a neuropterous insect, which he states closely resembles that of the living Corydalis of Carolina.—Wonders of Geology, 2nd edit., vol. ii. p. 679.

Genus, Species, and Reference.	Plate and Figure. The numerals refer to the Plates which illustrate the memoir.	Formation. Coal Measures. Penneystone.	White Flat.	Blue Flat.	Carbonif. Limestone.	Old Red Sandstone.	Upper Ludlow.	Aymestry Limestone.	Lower Ludlow.	Wenlock Limestone.	Wenlock Shale.	Caradoc Sandstone.
CRUSTACEA.												
Asaphus caudatus, *Brongn.*	2. f. 4.	...	...	...	...	...	...	...	...	*	*	...
——— tuberculato-caudatus, Silur. Syst.	7. f. 8 *b*.	...	...	...	...	...	...	...	...	*	...	...
——— longi-caudatus, Silur. Syst.	14. f. 11–14.	...	...	...	...	...	...	...	...	*	*	...
Calymene Blumenbachii, *Brongn.* i. 1.	.....	...	...	...	...	...	...	...	...	*	...	...
Limulus anthrax	XLI. f. 1-4.	...	*	...	...	...	...	...	...	...	...	...
——— rotundatus	XLI. f. 5-7.	...	*	...	...	...	...	...	...	...	...	...
——— trilobitoides, *Buckl.* Bridgew. T. XLVI″. f. 3	XLI. f. 8.	...	*	...	...	...	...	...	...	...	...	...
Apus dubius	XLI. f. 9.	...	*	...	...	...	...	...	...	...	...	...
Cypris inflata. In the Freshwater Limestone of the Coal Measures. Silur. Syst., p. 84., Wood-Cut.	.....	*	?	...	...	...	...	...	...	...	...	...
ANNULATA.												
Spirorbis Lewisii? Silur. Syst.	8. f. 1.+	...	...	...	...	...	...	...	...	*	...	...
——— ———	XL. f. 1[1].	*	...	...	...	...	...	...	...	...	...	...
Microconchus carbonarius, in the Freshwater Limestone of the Coal Measures. Silur. Syst., p. 84, Wood-Cut.	.....	...	...	...	...	...	...	...	...	...	...	...
CONCHIFERA.												
Mya rotundata? Silur. Syst.	6. f. 1.	...	...	...	...	...	...	*	...	...	...	...
Donax? sulcata	XXXIX. f. 1.	*	...	...	...	...	...	...	...	...	...	...
Venus? carbonaria	XXXIX. f. 2.	*	...	...	...	...	...	...	...	...	...	...
Cypricardia impressa? Silur. Syst.	5. f. 3.	...	...	...	...	...	*	...	...	...	...	...
——— undata? Silur. Syst.	5. f. 4.	...	...	...	...	...	...	*	...	...	...	...
Nucula equalis	XXXIX. f. 3.	*	...	...	...	...	...	...	...	...	...	...
——— accipiens	XXXIX. f. 4.	*	...	...	...	...	...	...	...	...	...	...
——— acuta	XXXIX. f. 5.	*	...	...	...	...	...	...	...	...	...	...
Unio Urii, Fleming Brit. Anim., p. 417. Ure Ruthug. 16, f. 4.	XXXIX. f. 6.	*	...	...	...	...	...	...	...	...	...	...
—— Ansticei	XXXIX. f. 7.	*	...	...	...	...	...	...	...	...	...	...
—— parallelus	XXXIX. f. 8.	*	...	...	...	...	...	...	...	...	...	...
—— dolabratus	XXXIX. f. 9.	*	...	...	..	...	...	...	...	...	...	...
—— modiolaris	XXXIX. f. 10[1].	...	...	...	...	...	...	...	...	...	...	...
—— Phaseolus	XXXIX. f. 11.	...	*	*	...	...	...	...	...	...	...	...
—— aquilinus	XXXIX. f. 12.	...	*	*	...	...	...	...	...	...	...	...
—— centralis	XXXIX. f. 13.	*	*	*	...	...	...	...	...	...	...	...
—— robustus	XXXIX. f. 14.	*	...	...	...	...	...	...	...	...	...	...
—— Listeri, var?, Sowerby	.....	*	...	...	...	...	...	...	...	...	...	...
—— acutus, Min. Con.	23. f. 5-7.	*	*	*	...	...	...	...	...	...	...	...
—— subconstrictus, Min. Con.	23. f. 1-3.	*	*	*	...	...	...	...	...	...	...	...
Modiola carinata	XXXIX. f. 15[1].	..	..	...	...	...	...	...	...	..	...	...
Mytilus triangularis	XXXIX. f. 16[1].	...	...	...	...	...	...	...	...	...	...	...
Avicula quadrata	XXXIX. f. 17.	...	*	...	...	...	...	...	...	...	...	...
——— modiolaris	XXXIX. f. 18.	...	*	...	...	...	...	...	...	...	...	...
Pecten gentilis	XXXIX. f. 19.	*	...	...	...	...	...	...	...	...	...	...
—— scalaris	XXXIX. f. 20.	*	...	...	...	...	...	...	...	...	...	...
—— papyraceus, Min. Con.	354.	*	...	...	...	...	...	...	...	...	...	...
Orbicula reflexa, Min. Con.	506. f. 1.	*[2]	...	...	...	...	...	...	...	...	...	...
Leptæna lata, (*Von. Buch.*) Silur. Syst.	3. f. 10 *b*. 5. f. 13.	...	...	...	...	...	*	*	...	*	...	...
——— euglypha, (*Dalm.*) Silur. Syst.	12. f. 1.	...	...	...	...	...	...	...	...	*	...	...
——— depressa, Min. Con.	459. f. 3.	...	...	...	...	...	...	...	...	*	*	...
——— hemispherica, Min. Con.	561.	...	...	...	*	...	...	...	...	...	...	...
——— gigantea, Min. Con.	320.	...	...	...	*	...	...	...	...	...	...	...

[1] Found in the Crawstone.

[2] Found also in the Blackstone and Chance Penneystone.

Genus, Species, and Reference.	Plate and Figure. The numerals refer to the Plates which illustrate the memoir.	Formations. Coal Measures. Pennsylvanian stone.	White Flat.	Blue Flat.	Carboniferous Limestone.	Old Red Sandstone.	Upper Ludlow.	Aymestry Limestone.	Lower Ludlow.	Wenlock Limestone.	Wenlock Shale.	Caradoc Sandstone.
Leptæna scabricula, Min. Con.	64. f. 1.	*[1]	...	...	...	...	...	...	...	...	...	..
——— concinna, Min. Con.	318. f. 1.	*	...	...	...	...	...	...	...	...	...	...
Atrypa affinis, Min. Con.	324. f. 2.	...	...	...	...	...	...	*	...	*	...	...
——— galeata, (*Dalm.*) Silur. Syst.	8. f. 10. 12. f. 4.	...	...	...	...	...	...	...	...	*	...	...
——— aspera, (*Dalm.*) Silur. Syst.	12. f. 5.	...	...	...	...	...	...	...	...	*	...	...
——— tenuistriata, Silur. Syst.	12. f. 3.	...	...	...	...	...	...	...	...	*	...	...
Spirifera radiata, *M. C.* Silur. Syst.	12. f. 6.	...	...	...	...	...	...	...	...	*	...	...
——— pisum? Silur. Syst.	13. f. 9.	...	...	..	...	...	...	...	...	...	*	...
——— crispa? Silur. Syst.	12. f. 8.	...	...	...	...	...	...	...	...	*	...	...
——— sinuata, (*Linn. Trans.*) Silur. Syst.	13. f. 10.	...	...	...	...	...	...	...	...	...	*	...
——— bisulcata, Min. Con. 494.	XXXIX. f. 21.	*	...	...	...	...	...	...	...	..	...	...
——— semicircularis, *Phillips*, Geol. York	19. f. 15, 16.	*	...	...	...	...	...	...	...	...	...	...
Orthis lunata, Silur. Syst.	3. f. 12 *d*. 5. f. 15.	...	...	...	...	...	...	*	...	...	...	...
——— orbicularis, Silur. Syst.	5. f. 16.	...	...	...	...	...	...	*	...	...	...	...
——— hybrida, Silur. Syst.	13. f. 11.	...	...	...	...	...	...	...	...	*	*	...
——— rustica, Silur. Syst.	12. f. 9.	...	...	...	...	...	...	...	...	*	...	...
——— testudinaria, Silur. Syst.	20. f. 9, 10.	...	...	...	...	...	...	...	...	...	*	...
——— alternata, Silur. Syst.	19. f. 6.	...	...	...	...	...	...	...	...	...	...	*
Terebratula lacunosa, Silur. Syst.	5. f. 19. 12. f. 10.	...	...	...	...	...	...	*	...	*[2]	...	...
——— pulchra, Silur. Syst.	5. f. 21.	...	...	...	...	...	...	*	...	...	...	...
——— cuneata, (*Dalm.*) Silur. Syst.	12. f. 13.	...	...	...	...	...	...	...	...	*	...	...
——— bidentata, (*Hising.*) Silur. Syst.	12. f. 13 *a*.	...	...	...	...	...	...	...	...	*	...	...
——— spherica, Silur. Syst.	13. f. 17.	...	...	...	...	...	...	...	...	...	*	...
——— sacculus, *M. C.*	446. f. 1.	...	...	...	*	...	...	...	...	...	...	...
——— Wilsoni, *M. C.*	118. f. 3.	...	...	...	...	...	...	*	...	...	...	...
——— pleurodon, *Phillips*, Geol. York.	12. f. 16.	*	...	...	...	...	...	...	...	...	...	...
——— radialis, *Phillips*, Geol. York.	12. f. 40, 41.	...	...	...	...	...	...	...	...	...	...	...
Pentamerus lævis, *M. C.*	28.	*	...	...	...	...	...	...	...	...	...	*
Lingula cornea, Silur. Syst.	3. f. 3.	...	...	...	...	*	...	...	...	...	...	...
——— Lewisii, Silur. Syst.	6. f. 9.	...	...	...	...	...	*	...	...	...	...	...
——— minima, Silur. Syst.	5. f. 23.	...	...	...	...	...	*	...	...	...	...	...
——— parallela? *Phillips*, Geol. York.	11. f. 17, 19.	*[2]	...	...	...	...	...	...	...	...	...	...
——— ———	...	*[1]	...	...	...	...	...	...	...	...	...	..
MOLLUSCA.												
Globulus vetustus	XXXIX. f. 22.	*	...	...	...	...	...	...	...	...	...	...
Littorina? obscura.	XXXIX. f. 23.	*	...	...	...	...	...	...	...	...	...	...
Euomphalus sculptus, Silur. Syst.	12. f. 17.	...	...	...	...	...	...	...	...	*	...	...
——— funatus, Min. Con.	450. f. 1, 2.	...	...	...	...	...	...	...	...	*	...	...
——— rugosus, Min. Con.	52. f. 2.	...	...	...	...	...	...	...	...	*	...	...
——— discors, Min. Con.	52. f. 1, 3.	...	...	...	...	...	...	...	...	*	...	...
Trochus? Usocona.	XL. f. 1.	*	...	...	...	...	...	...	...	...	...	...
Turritella? clavata	XXXIX. f. 24.	*	...	...	...	...	...	...	...	...	...	...
———? minima	XXXIX. f. 25.	*	...	...	...	...	...	...	...	...	...	...
Polyphemus? (*Montfort*) fusiformis	XXXIX. f. 26.	*	...	...	...	...	...	...	...	...	...	...
Conularia quadrisulcata, Min. Con. CCLX. 3—6.	XL. f. 2.	*[1]	...	...	...	...	...	...	...	...	...	...
Orthoceras annulatum, Min. Con.	133.	...	...	...	...	...	...	...	*	*	*	...
——— giganteum, Min. Con.	246.	...	...	...	...	...	...	...	...	*	...	...
——— scalpratum	XL. f. 3.	*	...	...	...	...	...	...	...	...	...	...
——— ———	XL. f. 4.	*	...	...	...	...	...	...	...	...	...	...
Nautilus clitellarius	XL. f. 5 *a* & *b*.	*	...	...	...	...	...	...	...	...	...	...
——— concavus	XL. f. 6.	*	...	...	...	...	...	...	...	...	...	...
——— subsulcatus, var.	XL. f. 7.	*	...	...	...	...	...	...	...	...	...	...
——— armatus	XL. f. 8.	*	...	...	...	...	...	...	...	...	...	...
——— falcatus	XL. f. 9.	*	...	...	...	...	...	...	...	...	...	...
Bellerophon hiulcus, var. *Fleming*	XL. f. 10.	*	...	...	...	...	...	...	...	...	...	...
——— navicula	XL. f. 11.	*	...	...	...	...	...	...	...	...	...	...
——— apertus, Min. Con.	469. f. 1.	...	...	...	*	...	...	...	...	...	...	...

[1] Found likewise in the Chance Penneystone. [2] Found also in the Top coal bass.

Genus, Species, and Reference.	Plate and Figure. The numerals refer to the Plates which illustrate the memoir.	Formations. Coal Measures. Penney-stone.	White Flat.	Blue Flat.	Carbonif. Limestone.	Old Red Sandstone.	Upper Ludlow.	Aymestry Limestone.	Lower Ludlow.	Wenlock Limestone.	Wenlock Shale.	Caradoc Sandstone.
Cornulites serpularius (*Schloth.*) Silur. Syst.	26. f. 5-9.	...	...	...	...	...	...	...	...	*	...	...
Tentaculites ornatus, Silur. Syst.	12. f 25.	...	...	...	...	...	...	...	...	*	...	...
——— annulatus (*Schloth.*) Silur. Syst.	19. f. 16.	...	...	...	...	...	...	...	...	...	...	*
PISCES.												
Gyracanthus formosus,[1] *Agass.* vol. iii. p. 17.	5. f. 2–6.	*	*	...	...	...	...	...	...	...	...	...
Cochliodus[2], *Agass.* vol. iii. p. 113.	XLI. f. 14.	*	...	...	...	...	...	...	...	...	...	...
Hybodus[3] ? *Agass.* vol. iii. p. 41.	XLI. f. 12, 13.	*	...	...	...	...	...	...	...	...	...	...
Megalichthys Hibbertii,[4] *Agass.* vol. ii. p. 87.	XLI. f. 10, 11.	*	...	..	...	...	...	...	...	...	...	...
Holoptychius Hibbertii,[5] *Agass.* MS.	XLI. f. 15.	*	...	...	...	...	...	...	...	...	...	...
Pleuracanthus, *Agass.* vol. iii. p. 66.	.....	*	...	...	...	...	...	...	...	...	...	...

[1] Bones of the head and scales.

[2] A tooth, see Plate XLI. fig. 14.

[3] A spine and tooth, represented in Plate XLI. fig. 12, 13, are assigned to this genus provisionally, as they may possibly belong to the Coal Measure, genus Diplodus, the characters of which have not yet been published by M. Agassiz.

[4] Bones of head, see *ante*, p. 443, and Pl. XLI. fig. 10, 11.

[5] The spine given in Pl. XLI. fig. 15, is placed with doubts in this genus, its state of preservation not being good. The spine is round but compressed, and is armed with two opposite rows of teeth or tubercles inclined downwards. There are no traces of the curve mentioned by M. Agassiz as one of the distinguishing characters of the genus.

Remains of Gyracanthus, Hybodus ? and Megalichthys are found also in the Chance Penneystone, Top coal bass, and Flint coal bass.

List of the Faults producing a vertical difference of 20 feet or more, in the Coalbrook Dale District.

(D.)

In the first column are given the numbers of the Faults as indicated in the Map, or the first letters of those which are designated by names. In the second column the names without an asterisk are those applied to some of the larger Faults by the people in the country; those with an asterisk have been proposed by the author. The headings explain the nature of the 3rd, 4th, 5th, and 6th columns. In the 7th the connexion of the different Faults is given. Thus, opposite Fault 5,—4, V. 8, signify that the Fault, Number 5, is connected at one extremity with Fault 4, and at the other with Fault 8. In the same way ranging with Fault 2 is, Trap II. 3, or Fault 2, abuts against Trap at one end and joins Fault 3 at the other. Again, opposite Randley Fault, *o*, Ra, *g*, express that the Randley Fault, Ra, at one extremity gradually thins out *o*, and at the other is connected with the great east Fault *g*. In the next instance the case is more complex. Opposite the Lilleshall Fault is the expression, *b*, *k*, $\succ l$, $-l$, *g*, $\succ x$, which means that the Boundary Fault *b* and Ketley Fault *k* unite or merge $\succ$ into the Lilleshall Fault *l*; and that the Lilleshall Fault (*l*) at the other extremity, and the great east Fault (*g*) unite and extend to an unknown distance *x*. Where *o* occurs on each of the Roman numerals the Fault thins out at each extremity as *o*, XII. *o*. Lastly *x*, LXIII. *x*, mean that the fault extends indefinitely.

	NAME.	Average Amount of Disturbance.	Direction.	Ascertained Extent of range.	Side of Highest Level.	Rise, Connection, and Termination.	REMARKS.
		feet.		m. fur.			
l.	Lilleshall+	3000?	N. 35° E.	3 2	S.E. by E.	*b*, *k*, $\succ l$, $-l$, *g*, $\succ x$.	Brings the Silurian and igneous rocks of Lilleshall into contact with the New Red Sandstone.
g.	Great East+...	1000?	N. 20° E.	8 0	W.N.W.	*l*, G. *lim.*	Bounds the coal field to the eastward, bringing the measures on a level with the New Red Sandstone. It has not been positively proved underground, except at Pitchcroft. It is deflected in its course.
1.	.....	20	N. 23° E.	1 0	W.N.W.	Trap, I. 3.	Visible in the lime quarry at Lilleshall.
2.	.....	45	N. 23° E.	1 0	W.N.W.	Trap, II. 3.	Ranges parallel to 1 at the distance of a few yards, and is visible in the lime quarry.
3.	.....	36	N. 10° E.	2? 0	N. by E.	*l*, III. *x*.	At the Pitchcroft pits the fall is 36 feet, but it increases apparently as it trends southward.
4.	.....	15—50	N. 53° W.	1 0	S.W. by S.	*l*, IV. *o*.	Increases as it approaches the Lilleshall but vanishes just before it reaches the Lightmoor fault.
b.	Boundary	2200?	N. 60° E.	3 4	S.E. by S.	Trap. *b*, $k \succ l$.	Bounds the coal measures to the N.W., abutting them against the New Red Sandstone. It is joined at Donnington by the Ketley fault, and the union of the two forms the Lilleshall fault. In places basalt appears along this fault.
k.	Ketley.....	30—600	N. 40° E.	6 0	S.E.	*l*, K, *x*.	One of the earliest known large faults in the coal field. It is frequently perpendicular and the sides of it often gape. At its junction with the Boundary, it splits into numerous fan-shaped branches. It decreases rapidly as it trends southward.
li.	Lightmoor.....	300—600	N. 35° E.	6 3	N.W. by W.	*g*, Li. *bro.*	Its course through the Wenlock shale and limestone cannot be ascertained with the same exactitude as through the coal field. Its length is no doubt much greater than that which is here given. It will be perceived, that it does not range in a perfectly straight line. This is one of the best known and most important faults in the coal field. Its effects vary greatly owing to its frequent junction with other faults.
5.	.....	24	N. 15° W.	0 5	W. by S.	4, V. 8.	
6.	.....	24	N. 58° W.	1 1	S.W. by S.	*b*, VI. *li.*	Increases but subdivides as it approaches the Boundary fault. It crosses 5, by which it is slightly deflected.
7.	.....	24	N. 53° W.	1 1	S.W. by S.	*b*, VII. *li.*	It presents the same phenomena as No. 6.
8.	.....	25	N. 33° E.	1 0	W.N.W.	5, VIII. *li.*	Decreases as it proceeds from the Lightmoor fault, of which it is a branch; the chief fracture of the Lightmoor fault bending a few degrees eastward at the point of divergence.
9.	.....	27	N. 88° E.	0 2	S.	8, IX. *li.*	At its intersection with 8, no alteration of level is produced; the faults neutralising each other, but shortly resume their previous condition. See fault 12.
10.	.....	24	N. 10° W.	1 4	W. by S.	*b*, X. *li.*	Increases and subdivides towards *b*.
11.	.....	24	N. 40° E.	0 5	S.E. by E.	10, XI. 13.	Perpendicular, and from 20 to 30 yards broad. It ramifies towards 10.
12.	.....	25	N. 88° E.	0 6	S.	*o*, XII. *o*.	Apparently a continuation of 9; but the continuity being partially destroyed by 8, it is considered as a distinct fault: it traverses 10 without either fault being affected.
13.	.....	20	N. 72° W.	0 7	S.S.W.	*k*, XIII. 10.	
w.	Woombridge+	30—90	N. 67° W.	1 0	N.E. by N.	*k*, W. *r.*	Increases towards the Rock fault.
r.	Rock	20 - 100	N. 50° E.	1 0	N.W.	*w*, R. 37.	This fault is very irregular; on meeting 10 it is deflected several degrees eastward, and it terminates abruptly against 37.
wr.	Wrekin+	4000?	N. 50° E.	?	S.E.	*x*.	The great dislocation ranging parallel to the igneous axis of the Wrekin, is apparently deflected slightly more to the northward by its junction with the Steeraways line of dislocation. The diagonal of the two passing through Kinley Wick, where we find a protruded boss of basalt.
14.	.....	30	N. 45° W.	1 0	S. 45° W.	*o*, XIV. 16.	
15.	.....	16—30	N. 70° E.	0 $\frac{1}{2}$	N.N.W.	*k*, XV. 16.	Increases rapidly in vertical importance towards *k*.
16.	.....	16—100	N. 25° E.	0 4	W.N.W.	*k*, XVI. 15.	Ditto ditto.
17.	.....	0 -60	N. 63° E.	0 3	S.S.E.	*o*, XVII. *b*.	Thins off quickly as it recedes from *b*. The dip on the side of lowest level is more than double that on the rise.
18.	.....	0—40	N. 63° E.	0 4	S.S.E.	*o*, XVIII. *b*.	The phenomena are the same as in No. 17.
a.	Arleston.....	0—100	N. 25° to 45° E.	3 4	E.S.E.&S.E.	*o*, A. *x*.	Commencing between the villages of New Hadley and Ketley, it bends at Ketley and again at Steeraways. At a mile from its rise its effects are 100 feet. Past Steeraways it again decreases slightly, afterwards the strata which are nearly level on the rise of this fault, dip rapidly towards it, in the swamp.
19.	.....	28	N. 35° E.	0 5	N.W. by W.	*o*, XIX. *o*.	Runs parallel to *k*.
20.	.....	40	N. 50° W.	0 6	N.E. by N.	*k*, XX. *a*.	From the rise side of this fault, the strata dip uninterruptedly to New Hadley.

	NAME.	Average Amount of Disturbance.	Direction.	Ascertained Extent of range.	Side of Highest Level.	Rise, Connection, and Termination.	REMARKS.
		feet.		m. fur.			
21.	.....	60—300	N. 35° E.	2 2	N.W.	20, XXI. *x.*	At Little Wenlock this fault brings the edges of the coal measures against trap rocks, but there is no mineralogical change: the strata dip rapidly towards this fault; the trap at Saplin Farm is probably on the prolongation of it.
22.	.....	20	N. 65° W.	0 1½	N.N.E.	21, XXII. *k.*	Brings in the Penneystone measure.
23.	.....	80	N. 65° W.	1 0	N.N.E.	Trap, XXIII. *k.*	Crosses 20 and *a* without producing any apparent change in either, and it is visible in the lime quarries as well as at the New Works.
24.	.....	20	N. 40° E.	0 6	S.E.	20, XXIV. *x.*	
25.	.....	90	N. 15° W.	0 2	W. by S.	21, XXV. *k.*	Forms with 20, *k* and 22, a small deep trough, inclosing all the principal measures which are thrown out all around.
26.	.....	24	N. 60° W.	0 2	N.E. by N.	Trap, XXVI. *a.*	Runs at right angles to the igneous axis of Steeraways.
27.	.....	24	N. 60° W.	0 2	S.W. by S.	Trap, XXVII. *a.*	Ditto. ditto.
28.	.....	27	N. 77° E.	0 3½	S. by E.	Trap, XXVIII. *a.*	Runs diagonally to ditto.
29.	.....	25	N. 53° W.	0 3	S.W. by S.	Trap, XXIX. *a.*	At right angles to ditto.
30.	.....	30	N. 62° W.	0 1½	S.S.W.	*r*, XXX. *li.*	Forms with *r* and *li* a detached triangular trough.
31.	.....	30	N. 55° W.	0 2	S.W. by S.	*r*, XXXI. *li.*	The strata between these two faults are elevated 30 feet.
31*	.....	30	N. 65° W.	0 2	S.W. by S.	*r*, XXXI.* *li.*	
32.	.....	21	N. 80° E.	0 4	S. by E.	*r*, XXXII. *li.*	
33.	.....	20	N.	0 6	E.	*r*, XXXIII. *li.*	This is almost an unique example of a series of four small fractures ranging in planes parallel to and at short distances from each other. One fault commencing at a little distance from the termination of another.
34.	.....	24	N. 27° E.	0 2	E.N.E.	*r*, XXXIV. *o.*	
35.	.....	120	N. 48° E.	0 5	S.E.	*r*, XXXV. 37.	Forms with part of rock 37, a singular deep trough in the midst of a shallow portion of the field.
36.	.....	60	N. 50° W.	0 0½	N.E.	*r*, XXXVI. 35.	
37.	.....	100	N.W.	0 5	S.	*r*, XXXVII. 35.	
38.	.....	50	N. 34° W.	1 1?	S.W. by W.	*k*, XXXVIII. *li*?	
38*	.....	40	N. 5° E.	0 3	E.	37, XXXVIII.38.*	
39.	.....	60	N. 28° E.	2 0	E.S.E.	*k*, XXXIX. *x.*	Not well known. Runs from the Ketley fault at Lawley, past the foot of Small Hill towards Coalmoor Farm south, where it is lost.
40.	.....	150	N. 50° W.	0 6	S.W.	*g*, XL. *li.*	The course of this fault is not very accurately known. The triangular district included between it and the Lightmoor and the Great East faults, contains the deepest-seated portion of the coal measures. In 1838 there was but one pit in this district.
41.	.....	35	N. 80° E.	0 2	S.	40, XLI. 42.	
42.	.....	50—70	N. 27° E.	1 2	E.S.E.	*li*, XLII. 48.	
43.	.....	60	N. 65° E.	1 1	N.N.W.	*g*, XLIII. 48.	
ra.	Randley.....	0—200	N. 33° E.	2 0	N.W. by W.	*o*, Ra. *g.*	Commences at Sturchley, increases rapidly at Randley, where the fall is 120 feet, a quarter of a mile beyond it is 180 feet, and in the same proportion to Priorslee.
44.	.....	0—75	N. 27° E.	0 6	E.S.E.	*li*, XLIV. *o.*	Thins out at Langley.
45.	.....	75	N. 77° E.	0 2½	N. by W.	44, XLV. 48.	Forms with 44 and 48 a small triangular area elevated 75 feet on all sides.
46.	.....	75	N. 77° E.	0 2⅓	S. by E.	44, XLVI. 48.	Forms with 45 a small narrow trough 75 feet deeper than the measures on either side, whilst those included in the trough are much pressed up on the sides.
47.	.....	40	N. 10° E.	0 6	W. by N.	48, XLVII. *ra.*	
48.	.....	90	N. 53° W.	0 6	S.W. by S.	*ra*, XLVIII. *li.*	Very variable in size and vertical importance in consequence of its junction with so many faults.
49.	.....	21	N. 55° W.	0 1½	S.W. by S.	47, XLIX. *ra.*	
lim.	Limestone	150	N. 57° E.	2 6	N.W. by N.	.....	An anticlinal line, but known in the country as the limestone fault. (See page 458, bottom line.)
m.	Madeley.....	2000?	N. 23° E.	2 4	W.N.W.	*s*, M. *x.*	Ranges in an irregular line, the coal measures rise in steps towards it; at Blisses, the coal is sooty, the ironstone is red as if calcined, and the shales are hardened, indicating the probable proximity of igneous rocks, which however neither reach the surface, nor have been seen under ground. It resembles in these respects, therefore, fault *b*, and is probably a disjointed continuation of *g*.
50.	.....	25	N. 75° W.	2 0	S. by W.	*bro*, L. *m.*	Follows the course of the Severn.
51.	.....	24	N. 23° W.	0 5	E.N.E. W.S.W.	50, LI. 54 or 52.	Remarkable for destroying the parallelism of the disjointed strata, and its consequent change of relative level at each extremity, being at one end E.N.E. and W.S.W.
52.	.....	30	N. 65° E.	0 7	S.S.E.	50, LII. 54.	
53.	.....	24	N. 45° W.	0 5	S.W.	*m*, LIII. 52.	
54.	.....	30—6	N. 42° E.	0 3	N.W.	*bro*, LIV. 52.	
bro.	Broseley.....	220	N. 38° W.	2 4	S.W. by W.	*s*. Bro. *li.*	Increases rapidly towards *bro.* Breaks the connection of the limestone escarpment between Benthall Edge and Lincoln Hill. Too well known at Broseley by its causing a speedy and final outcrop of the greater portion of the coal measures.
55.	.....	30	N. 12° E.	1 4	E. by S.	*bro*, LV. 56.	Very uniform in vertical importance.
56.	.....	300?	N. 37° W.	?	S.W. by W.	*s*, LVI. *x.*	Brings up the Ludlow rocks at Barrow. Probably intersects *li*, at Tickwood.
s.	Swinney+.....	100—2000	N. 68° E.	3 0?	N.N.W.	*x*, S. 8.	An important disturbance bringing up the Silurian rocks and throwing out all but the lowest strata of the coal measures. It is well exhibited at Swinney and at the Dean Corner.
57.	.....	100	N. 10° E.	1 0?	E. by S.	*x*, LVII. *s*?	The strata dip rapidly to this fault on the swamp side.
58.	.....	60?	N. 25° E.	1 0	W.N.W.	*s*, LVIII. 60.	The strata rise at an angle of 45° towards this fault in Turner's yard pit.
59.	.....	300?	N. 38° E.	.....	N.W. by W.	*s*, LIX. *x.*	Is probably a continuation of the Madeley, after crossing the Swinney. It ranges parallel to a small anticlinal line.
60.	.....	60?	N. 85° E.	1 4	S.	59, LX. *x.*	
61.	.....	?	N. 40° E.	.....	N.W.	*x*, LXI. *x.*	The strata dip rapidly eastward from this fault, which ranges parallel to a small anticlinal line.
62.	.....	600?	N. 58° E.	1 2	N.W. by W.	*x*, LXII. *x.*	Is exposed near the Wren's Nest and also at the Hobbins.
63.	.....	.....	N. 2° E.	.....	W.	*x*, LXIII. *x.*	Seen in the brook below the Hook. It may only be connected with the fault which runs along Apley Coppice and near Sutton Maddock.
64.	Longwood+ ...	100	N.E.	?	N.W.	*x*, LXIV. *x.*	Parallel with the axis of the Wrekin.
65.	.....	100	N.E.	?	S.E.	*x*, LXV. *x.*	Ditto. ditto. These two faults form a narrow, deep trough in the small coal field of Longwood.

XXXIII*.—*Notice of a Letter from* Robert Were Fox, Esq., *to* Sir Charles Lemon, Bart., F.G.S., *relative to the Origin of Mineral Veins**.

[Read April 5, 1838.]

IT can scarcely be doubted, I think, that not only the mechanical deposits in mineral veins, but part, also, of those which are not mechanical, have been derived from the contiguous rocks or strata. It appears to me, however, that there has been another source from whence the latter may have been accumulated in almost indefinite quantities. I refer to the deeper parts of the original fissures in which the water, at a very high temperature and pressure, must have acted with great energy as a solvent, and become more or less charged with earthy and metallic salts; and ascending, under these circumstances, through the upper and cooler portions of the same fluid in the fissures, it naturally there produced deposits, in consequence of evaporation, reduction of temperature, and electrical agency. The circulation of upward and downward currents of water in the fissures must thus have continued until checked or superseded by too great an accumulation of different substances in the latter. The silicious deposits observed in the Geyser, and many other thermal springs, may be cited as examples of this kind of action.

The circulation of the water must, moreover, have had some influence in wearing away portions of the sides or walls of the fissures, and may have contributed to produce the smoothness for which they are sometimes so remarkable. The hanging walls, it may be presumed, were most exposed to the action of the *ascending* currents, and the foot walls to that of the *descending* ones; but I am not prepared to say whether or not such indications or distinctions are discoverable in mineral veins. The water-worn stones, which are occasionally met with in veins, may probably be referred to this cause.

I think it is evident that the arrangement of the ores, &c. in different rocks cannot be attributed to simple chemical affinity only, because the accumulation of the metallic masses is not found to depend merely on the nature of the containing rock; the ore of a given metal being sometimes found in

* Mr. Fox's first communication on this subject, which was read before the Society, was dated 19th March, 1836. See Geological Proceedings, vol. ii. p. 406.

granite, or in "*elvan,*" and not in "*killas,*" and sometimes in the latter, and not in either of the former. The remarkable concentration of the ores in some rocks in preference to others, seems rather to have resulted from their relative positions, or other circumstances of a local nature; and when I considered these very striking phænomena, which everywhere occur, and the actual proofs I had obtained of electrical action in many of our metallic veins, I felt compelled to adopt the conclusion, that some *definite* agency, such as electricity, must have produced or controlled those relations. My views on this part of the subject, I have more fully stated in my former communication, and I imagine I see more and more reason to believe that the eastward and westward tendency of metallic veins may be ascribed to the electro-magnetic influence of the earth. In some parts of the world there may be found considerable deviations from this bearing, owing, perhaps, to local circumstances; but the coincidence in their direction, generally speaking, is so decided, as clearly to indicate the operation of a general law. The greatest deviation in this county from the prevailing strike of our metalliferous veins has been supposed to exist in the tin veins of St. Just. I find, however, that their course, with respect to the *true meridian,* is, on the average, about N.W. and S.E., and that of the guides, or cross-courses, nearly north and south.

It is worthy of remark, that many of the large veins of oxide of iron found in Cornwall, Devon, and other districts, have a north and south bearing, or, rather, are nearly coincident with the magnetic meridian.

Much of the quartz in the cross courses may have been brought up in hot water from a great depth, and been gradually deposited as the successive portions of water became reduced in temperature. But the fibrous or crystalline texture of this quartz, with the axis of the crystals at right angles to the walls of the cross courses, is often so marked and decided, as to indicate the operation of some general cause or force having a definite direction*.

* I have obtained, by means of voltaic action, many veins of sulphate of zinc in clay, having a fibrous texture, perpendicular to the veins, like the quartz in cross courses, or like satin spar.

Falmouth,
January 28, 1837.

XXXIV.—*Notice on the Remains of a Fossil Monkey from the Tertiary Strata of the Sewalik Hills in the North of Hindoostan.*

By Capt. P. T. CAUTLEY, F.G.S., Bengal Artillery; and
H. FALCONER, Esq., M.D., Bengal Medical Service.

[Read June 14, 1837.]

THE most highly organized mammifers hitherto described in a fossil state, so far as our information extends, belonged to the *Cheiroptera*; and the instances of these on record are very few*. That quadrumanous remains should be wanting is by no means surprising, without the necessity of supposing that they did not exist. The countries of which the ancient races have been most completely investigated, had a climate unsuited to be the habitat of the tribe, as we now know it, when the more recent or superficial deposits were in progress of formation. If we refer to the remote epochs when the climate was suitable, and when genera now associated with the Monkeys were abundant, it is easy to conceive that the latter might have existed in numbers, without their remains being entombed. It requires in all instances many unconnected circumstances for the preservation of organic bodies, and their subsequent disclosure. Amongst the most important of these are the habits and organization of the animals themselves. As in the case of birds, it might be predicated, that this lucky concurrence of circumstances would be rare with quadrumanous remains. The very perfection in the organization of the Monkey entails, as a consequence, that his solid frame should seldom continue to indicate the previous existence of the individual. His admirable agility and social habits protect him against most aggressions. A flood might suffocate in their dens, over a large tract of country, the burrowing tribes; and might sweep from under the feet of the monkey hundreds of its herbivorous and predaceous fellow-tenants of the forest, and bury them in the near shingle or far-distant estuary, or drown and deposit them in the stagnant swamp—while he would remain secure. The tree on which he was perched might totter, and yield to the undermining cur-

* Brewster's Edinburgh Journal of Science.

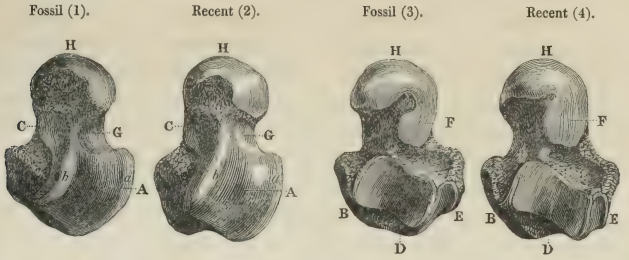
rent, and he still escape and feed on his wonted fruits, undisturbed by the destruction around. When the debt of nature comes to be paid, his carcase falls to the ground, and immediately becomes the prey of the numerous predaceous scavengers of torrid regions, the Hyæna, the Chacal, and the Wolf. So speedily does this occur, that in India, where Monkeys occupy, in large societies, mango groves around villages, unmolested and cherished by man, the traces of casualties among them are so rarely seen, that the simple Hindoo believes that they bury their dead by night.

When the ancient races of India began to open upon us in the new forms and the exuberant variety which the fossils of the Sewalik Hills exhibit, we were early led to anticipate that some trace of quadrumanous animals would soon be met with to perfect a series, which would be incomplete without them. Several months ago we became possessed of a solitary specimen, which put the matter, in our own minds, beyond all doubt. We deferred making it public, however, in the hope of soon finding specimens of the cranium and teeth; being unwilling to rest the announcement on any thing less characteristic. That chance has since fallen to our fellow-labourers in the pursuit, Messrs. Baker and Durand, of the Bengal Engineers, who have lately discovered a specimen, consisting of a considerable portion of the face, and the whole series of molars of one side, of a quadrumanous animal belonging to a much larger species than the bone we found.

Our fossil is the specimen which accompanies this communication. It is the astragalus of a right hind leg. It is completely mineralized, having a specific gravity of about 2·8, and it appears to be impregnated with hydrate of iron. Although but a solitary bone of the foot, the relations of structure are so fixed that the identity of the fossil is as certain as if the entire skeleton were before us. The very shallow excavation of the superior surface (A) [see wood-cut] for the pulley-like articulation with the tibia; the form and extent of the lateral articulating surfaces (B, C) for the external and internal malleoli; the considerable elongation of the apophysis for the head and neck of the bone (G, H); the slight obliquity with which it is sent off from the body; and the diagonal direction and form of the principal articulating surface (D) with the calcaneum, are characters which, taken in conjunction, incontestably prove that the fossil is a quadrumanous astragalus. It would be needless, therefore, to dwell on the points of difference between it and the astragali of those orders of Mammalia which have an allied form. It is only requisite to ascertain how it agrees with the corresponding bone in existing species of Quadrumana. It closely resembles, in size and general form, the astragalus of the *Semnopithecus Entellus*, which we send along with the fossil for comparison.

The principal dimensions are as follow :—

Dimensions.	Sewalik Fossil Monkey.	*Semnopithecus Entellus.*
Extreme length of astragalus	1·3 inch.	1·35 inch.
Extreme width of body of astragalus	1· ——	1·03 ——
Length of body	0·8 ——	0·85 ——
Greatest diameter of navicular head	0·65 ——	0·65 ——
Thickness of ditto	0·45 ——	0·5 ——



The chief peculiarities of the fossil astragalus, compared with that of the Entellus, are these :—The upper articulating surface for the tibia (A) is more convex than in the Entellus, and less square in the outline, the lateral margins (*a*, *b*) approximating as they run backwards; the outer one being also more elevated. The peroneal articulation (B) is precisely of the same form and extent as in the Entellus; and the rough fossa between it and the large calcanean surface (D) also corresponds. The articular surface (C) for the inner malleolus somewhat differs: in the fossil it is long, shallow, and rather pyriform in outline, while in the Entellus it is cup-shaped, deeper, and more extensive. The other pits and inequalities of the inner side correspond; but the entire surface slopes off more obliquely in the fossil. The great calcanean surface (D) has the same diagonal direction, with reference to the upper surface, as in the Entellus: it has also the same form, but it is more vaulted, and has less stretch and width. Its inner margin is bounded by the shallow, pulley-shaped fossa (E) for the tendon of the *flexor pollicis longus* muscle, entirely as in the Entellus; and the rough pit between it and the anterior calcanean surface (F) is alike in both. The head-and-neck apophysis is sent off as in the Entellus. The upper surface of the neck (G) is narrower and less sloped. The scaphoid surface of the head (H) is altogether less extensive. The head itself is not so thick and massive, and its long direction slopes more obliquely upwards than in the Entellus; its inferior articular surface is less, and there is a wide, rectagonal, rough gutter or fossa (x) running half way across, so as to make two surfaces. In the Entellus the fossa is obsolete, and

only indicated by a minute foramen, so that these articular surfaces run into one. This is the greatest difference observable in the fossil. The rough fossa at the outer side of the neck is alike in both.

With these inconsiderable peculiarities, the fossil agrees so closely in size and general form with the astragalus of the Entellus, that it probably belonged to the same sub-genus : still the points of difference are sufficient to leave no doubt, that the fossil must be assigned to a distinct species. In equalling the Entellus, it would belong to the larger Quadrumana. This is all the information the specimen conveys, regarding the animal from which it came ; but we may hope to meet with remains, which will develope its entire osteology, more especially that of the cranium and face. The fossil was found by a party of Hindoo collectors employed by us on the fossil tract of the Sewalik Hills ; and was brought to us mixed up with a promiscuous collection of the remains of the Hippopotamus, Mastodon, Ruminants, &c., like the specimens which have been sent to the Society. We have not therefore the means of knowing the exact locality where, and the circumstances under which, it was found.

The discovery is interesting in itself as supplying a deficient link in the series of the former tenants of the globe; but greatly more so in connexion with the races with which the fossil was associated. We have excavated from, or found in the debris of, different beds of the same formation which yielded the fossil astragalus, the remains of a species of Anoplotherium *, the *Crocodilus biporcatus* and *C.* (*Leptorhynchus*) *Gangeticus* †, respectively the Magar and Gavial, two species which at the present day inhabit the quiet waters of the Ganges. Here then are two most instructive facts : Quadrumana co-existed with a member of the oldest ascertained pachydermatous genus of Europe ; and two reptiles now the contemporaries of man in the East, lived, and may have laved, in the same waters along with a species of one of the mammiferous genera which characterise the Eocene period of the West ;— affording another illustration of constancy in the order of nature, of an identity of condition in the earth of the olden time with what it exhibits now, and of the invariableness of organized forms. The two decurrent ridges on the face which specifically distinguish the *C. biporcatus* of the present day,

* *Anoplotherium Sivalense*, (No. 6.) a new species, of a size somewhat larger than the *A. commune* of the Paris basin. The species is known to us by two upper jaws in our possession with the series of molars complete. We therefore quote it unhesitatingly.

† Known to us by specimens comprising the whole of the cranium and muzzle. They do not differ more from the existing individuals than these do from one another in varieties dependent on age and sex. Asiatic Researches, Vol. xix. Part II., Art. II.

are as marked and distinct on the individuals which existed perhaps centuries of centuries ago; and an ankle bone of the Sewalik fossil Monkey so closely resembles that of a living species, that it is difficult to explain the difference.

The Sewalik fossils abound in monuments of this sort. There is a mixture of the new and of the old, of the past and of the present, of familiar with surprising forms, together with a numerical richness, such as no other explored region has exhibited within so comparatively limited a space. The Camel*, the Antelope, and Anoplotherium, have been found, intermixed with each other in the *same bed*. There are remains of the Elephant, Mastodon, Hippopotamus†, Anthracotherium, Rhinoceros‡, Hog, and Horse; the Tapir alone of the large existing Pachydermata being without a representative. In the Sivatherium§ is seen a huge Ruminant exceeding in size the largest Rhinoceros; it is also armed with four enormous sheathed horns, divided and foliated like the Dicranocerine Antelopes, and able to contend for mastery with the Mastodon. Contrasted with him in the same family is the puny Musk Deer, scarcely larger than a Hare. There are the Cat‖ and the Dog tribe, the Hyæna, Bear¶, and Ratel**, and other Carnivora. In the feathered races, there are Grallæ, greatly surpassing in size the Gigantic Crane of Bengal (*Ciconia Argala*). Among the Reptilia, besides the Magar and Gavial, there were other Crocodiles†† of enormous bulk, approaching the largest Saurians; and the Testudinata, which have hitherto held but a humble rank beside their Saurian co-ordinals, here show their giant representatives. In addition to numerous species of Emys and Trionyx not bigger than the

* *Camelus Sivalensis* (Nob.), Asiatic Researches, Vol. xix. Part II., Art. X., a species of the size of the existing Camel.

† Asiat. Res., Art. III. *Hippopotamus Sivalensis* (Nob. & *H. dissimilis*, Nob.).

‡ Journal of the Asiatic Society, Vol. iv. p. 706, and vol. v. p. 486.

§ Asiat. Research. *ut supra*, Art. I. *Sivatherium Giganteum* (Nob.). Since the memoir was printed, Col. Colvin, Bengal Engineers, has got a specimen of the cranium with the bases of the four horns attached, and we have in our possession an almost entire rear horn, which has given the characters noted above.

‖ *Ibid.* Art. XI. *Felis cristata* (Nob.). Smaller than the Tiger.

¶ *Ibid.* Art. XII. *Ursus Sivalensis* (Nob.). Size of the *U. Spelæus*.

** Messrs. Baker and Durand, Journ. Asiatic Society, Vol. v. p. 581.

†† *C. Leptorhynchus crassidens* (Nob.), an immense species far exceeding existing ones, and forming a passage from the Gavials into the true Crocodiles. It has the cylindrical muzzle and synostorized lower jaw of the former with the blunt thick teeth of the latter.

small Terrapins of the sluggish brooks of Hindoostan, we possess humeri and femora of this tribe (with corresponding fragments of the bucklers) as large as the equivalent bones of the Indian Rhinoceros. As the Pterodactyle more than realized the most extravagant idea of the Winged Dragon, so does this huge Tortoise come up to the lofty conceptions of Hindoo mythology: and could we but recall the monsters to life, it were not difficult to imagine an Elephant supported on its back.

Suharun Poor, Nov. 24th, 1836.

XXXV.—*On the Formation of Mould.*

By CHARLES DARWIN, Esq., F.R.S., Sec. G.S.

[Read November 1, 1837.]

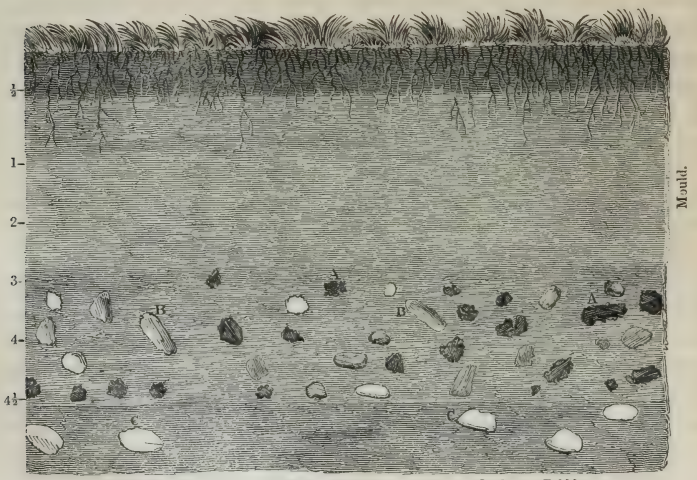
THE formation of the superficial layer of earth, commonly called vegetable mould, offers some difficulties in being fully understood, which apparently have been overlooked. In old pasture lands, the mould, to the depth of a few inches, differs but slightly, although resting upon various kinds of sub-soil. The uniform fineness of its particles is one of its chief distinguishing characters; and this may be well observed in a gravelly country, where a recently ploughed field immediately adjoins another, which has long remained undisturbed for grazing. In the latter, not a pebble will be seen, either on the surface or immediately below it; although in the ploughed field, a large proportion of the soil may be composed of small stones. From the prevailing use of the expression "vegetable mould," it would appear that its origin is generally attributed to some effect of vegetation; yet it is scarcely conceivable that the turf, in the case of the two adjoining fields, can have produced so remarkable a difference as that alluded to.

My attention was called to this subject by Mr. Wedgwood, who showed me, whilst I was staying at Maer Hall, in Staffordshire, several fields, some of which a few years previously had been covered with lime, and others with burnt marl and cinders. These substances, in every case, were buried some inches beneath the turf. In several parts of three grazing fields, I dug square holes, and obtained the following results:—1st. In some good pasture land which had been limed, without having been ploughed, about ten years before, the turf, or the layer in which the roots of the grasses are closely woven together, was about half an inch thick. At two inches and a half beneath this, or about three from the surface, a layer of lime, or a row of small aggregated lumps of it, formed a well-marked white line around the holes. The soil beneath this layer of lime was gravelly, or of a coarse sandy nature, and differed considerably from the mould nearer the surface. About three years ago cinders also had been spread on this field; but when I examined it, they were buried at the depth of one inch. They were not sufficiently numerous to form a layer, though a line of black spots could clearly be traced

parallel to and above the white one of lime. Some other cinders, which had been scattered in another part of this same field, only about half a year before, lay either on the surface or were entangled in the roots of the grass.

The second field, I mention only from the fact of the cinders being buried in such quantities, about three inches deep, as to form a stratum nearly one inch in thickness. The layer in some parts was so continuous, that the upper soil was united to the lower only by the longer roots of the grasses. The sub-soil was a red clay, and it occurred a little below the cinders.

The third case which I shall describe, is that of a field which, Mr. Wedgwood informed me, was waste land fifteen years ago. It was at that time drained, ploughed, harrowed, and well covered with burnt marl and cinders. It has not been disturbed since, and now supports a tolerably good but rather



A. Cinders. B. Burnt Marl. C. Quartz Pebbles.

coarse pasture. The section in this field, as represented in the wood-cut, was, turf half an inch; vegetable mould two inches and a half; a layer, one and a half inch thick, of fragments of burnt marl, (conspicuous from their bright red colour), of cinders, and a few quartz pebbles, mingled with earth. One of the angular fragments of burnt marl lying near the bottom, measured one inch in length by half an inch in breadth, and a quarter in thickness. Lastly, about four inches and a half below the surface, was the original black peaty soil. We thus find, beneath a layer, nearly four inches thick, composed of

fine particles of earth mixed with decayed vegetable matter, those substances which had been spread on the *surface* fifteen years before.

The appearance in all the above cases was, as if (in the language of the farmers, who are acquainted with these facts) the fragments had worked themselves down. It is, however, scarcely possible that cinders or pebbles, and still less powdered quick-lime, could sink through compact earth and a layer of matted roots of vegetables, to a depth of some inches; nor is it at all probable that the decay of the grass, although adding to the surface some of the constituent parts of the mould, should separate in so short a time the fine from the coarse earth, and accumulate the former on those objects, which so lately had been on the surface. I may add, that I have repeatedly observed fragments of pottery and bones buried beneath the turf, in fields near towns, (on which such substances are often thrown with manure); and as these fields did not appear to have been ploughed, the circumstance often surprised me. On the contrary, I have noticed in gardens lately dug, that the rain, by washing away the finer particles, leaves stones and other hard bodies accumulated on the surface.

The explanation of these facts, which occurred to Mr. Wedgwood, although it may appear trivial at first, I have not the least doubt is the correct one, namely, that the whole operation is due to the digestive process of the common earth-worm. On carefully examining between the blades of grass in the fields above described, I found scarcely a space of two inches square without a little heap of the cylindrical castings of worms. It is well known, that worms, in their excavations, swallow earthy matter, and that, having separated the portion which serves for their nutriment, they eject at the mouth of their burrows the remainder in little, intestine-shaped heaps. These partly retain their form until the rain and thaws of winter, as I have observed, spread the matter uniformly over the surface. The worm is unable to swallow coarse particles, and as it would naturally avoid pure or caustic lime, the finer earth lying beneath the cinders, burnt marl, or lime, would be removed, by a slow process, to the surface. This supposition is not imaginary; for in the field in which cinders had been spread out only half a year before, I actually saw the castings of the worms heaped on the smaller fragments. Nor, I repeat, is the agency so trivial as at first it might be thought: the great number of earth-worms, as every one must be aware who has ever dug in a grass field, making up for the insignificant quantity of the work which each performs. On the idea of the superficial mould having been thus prepared, the advantage of old pasture land, which it is well known farmers in England are particularly averse to break up, is explained; for the length of time required

to form a thick stratum must be considerable. In the peaty field, in the course of fifteen years, about three inches and a half had been well prepared; but it is probable that the process is continued, though at a very slow rate, to a much greater depth. Every time a worm is driven, by dry weather or any other cause, to descend deep, it must bring to the surface, when it empties the contents of its body, a few particles of fresh earth*. Thus, the manures added by man, as well as the original constituent parts of the soil, become thoroughly mingled, and a nearly homogeneous character is given to the whole.

Although the conclusion may appear at first startling, it will be difficult to deny the probability, that every particle of earth forming the bed from which the turf in old pasture land springs, has passed through the intestines of worms; and hence the term "animal mould" would in some respects be more appropriate than that of "vegetable mould."

I may conclude by remarking, that the agriculturist in ploughing the ground follows a method strictly natural; he only imitates in a rude manner, without being able either to bury the pebbles or to sift the fine from the coarse earth, the work which nature is daily performing by the agency of the earth-worm.

Note.—Since my communication on the "formation of mould," read on the 1st of November, I have received from Staffordshire an account which corroborates the statements then made, on the apparent sinking of objects placed on the surface of turf land. The first case I mention only because the substance is different from those previously described. In the spring of 1835 a boggy field, which had long remained as grass land, was so thickly covered with sand that the whole surface appeared of a red colour. At the present time, namely about two years and a half afterwards, the sand forms

* Mr. W. Lindsay Carnagie of Kimblethment, writing from Scotland to Mr. Lyell on the subject of this paper, as it is given in the Proceedings, states, that in clearing away a stiff clayey soil above a stone quarry, he has seen worms in small chambered passages between seven and eight feet below the surface. The black mould on the clay was there two feet thick. Mr. Carnagie observes, also, in his letter, that the Scotch farmers, from a belief that the lime itself has some tendency to sink, are afraid of putting it on ploughed land until just before it is laid down for pasture. He then adds, "Some years since, in autumn, I laid lime on an oat-stubble and ploughed it down; thus bringing it into immediate contact with the dead vegetable matter, and securing its thorough mixture through the means of all subsequent operations of fallow; I was considered, in consequence of the above prejudice, to have committed a great fault, but the result was eminently successful, and the practice *partially* followed. By means of Mr. Darwin's observations, I think the prejudice will be entirely removed."—June 1838.

a layer three-fourths of an inch below the surface, that thickness consisting of peaty soil.

The second case is more interesting. It has been ascertained that a field, which has since been ploughed, was covered about eighty years ago with marl; an imperfect layer of it, but sufficiently distinct to be traced, is now found at a depth, very carefully measured from the surface, of twelve inches in some parts and fourteen in others: the difference corresponding to the top and hollow of the ridges produced by ploughing. It is certain, the marl must have sunk or been buried before the field was ploughed, for otherwise the fragments would have been scattered in the soil: this conclusion, moreover, explains the circumstance of the layer being horizontal, whilst the surface is undulating. At the present time no plough could possibly touch the marl, as the land in this country is never turned up to a greater depth than eight inches. In the preceding communication, I have shown, that in a field lately reclaimed from being waste land, three inches of mould had been prepared by the worms in the course of fifteen years. We now find, that within a period of less than eighty years, (but how much less cannot be told, unless the date when the field was first ploughed were known) the earth-worms have covered the marl, which was originally strewed on the surface, with a bed of earth of an average thickness of no less than twelve or thirteen inches.

November 14, 1837.

XXXVI.—*Note on the Dislocation of the Tail at a certain point observable in the Skeleton of many Ichthyosauri.*

By RICHARD OWEN, Esq., F.R.S., F.G.S., Hunterian Professor to the Royal College of Surgeons, London.

PLATE XLII.

[Read March 21st, 1838.]

IF the *Cetacea*, like the *Enaliosauria*, were known only by their fossilized skeletons, it can hardly be doubted but that their conjecturally-restored figures as when entire and alive, would have resembled, so far at least as regards the form of the tail, those which have been published of the *Ichthyosaurus*. It may, I think, be safely affirmed, that the depressed or flattened shape of the small vertebral centres which terminate the gradually tapering tail in the skeleton of the Dolphins and Whales, would never of themselves have suggested the existence, in the recent and entire animal, of so large and important an instrument of locomotion, due entirely to unossified and readily decomposable material, which the actual presence of these fish-like Mammalia in the existing state of things, places beyond the necessity of speculation and conjecture.

The relation, however, which the slight modification of the terminal caudal vertebræ above alluded to bears to the presence of a large, horizontal, ligamentous fin, induced me some time ago to examine such specimens of skeletons of *Ichthyosauri* and *Plesiosauri*, having the tail complete, as were accessible in London, with the view to obtain evidence of the possible existence or trace of a similar structure in these species; but I was then unable to obtain from the imbedded vertebræ satisfactory proof of their exchanging a compressed for a depressed form at this part, or deviating in any way (save in size, number of articular surfaces, and, in the *Plesiosauri*, in the greater excavation of their anterior and posterior surfaces of articulation) from the rest of the vertebræ of the tail. I concluded, therefore, that these air-breathing inhabitants of the ancient deep, partly from being cold-blooded, as the condition of the ossification of their skeleton proves, and therefore slow breathers, and more especially on account of the superaddition of posterior paddles, were devoid of any locomotive organ analogous to the tail-fin of the *Cetacea*; and

that the hinder paddles principally served the purpose, in the absence of such a horizontal terminal fin, in bringing the head to the surface for the purpose of breathing.

Having recently examined many saurian skeletons now in London, the greater part of which have been disencumbered of their earthy shroud by the chisel of Mr. Hawkins, a condition of the tail which, on a former occasion, in a single instance had arrested my attention, but without calling up any theory to account for it, now more forcibly engaged my thoughts, from observing that it was repeated, with scarcely any variation, in five instances. The condition to which I allude is an abrupt bend or dislocation of the tail at about one-third of its whole length distant from the end; generally about the thirtieth caudal vertebra in the *Ichthyosaurus communis*; the terminal portion continuing, after the bend, almost as straight as the portion of the tail preceding it. In short, the appearance presented is precisely that of a stick which has been broken, and with the broken end still left attached, and depending at an open angle.

Now there is no modification of the vertebræ, where this bend takes place in the tail of the *Ichthyosauri* indicative of the tail having possessed, during the lifetime of the animal, greater mobility at this particular point than at any other; and it is scarcely possible to conceive how any force operating on the dead carcase at the bottom of the sea, or when it was imbedded in sedimentary deposits, could produce a fracture or dislocation of the tail at the precise point at which we find it in so many specimens, otherwise very dissimilar in regard to their general position and degree of perfection. I incline to believe, therefore, that the appearance is due to the operation of some force acting upon a ligamentous fin attached to that part of the extremity of the tail which is thus bent down; and that this force operated while the dead animal was floating and buoyed up by the gases generated by putrefaction, and when the ligaments and other connexions of the caudal vertebræ had been so far loosened as to allow the force which previously would have bent down the tail in a general curve like the top of a fishing-rod, to overcome the diminished resistance of the decomposing joints immediately proximal of its point of action, and dislocate the vertebræ at that part. The two portions of the tail, like the rest of the skeleton, would then continue to be held together by the common integument, until the rupture of the parietes of the abdomen would allow the pent-up gas to escape, and the body to sink to the bottom.

In thus descending through a sufficiently tranquil medium, the back being weighted with the heavy vertebral column, would be most likely the first part to touch the bottom; and if this consisted of soft clay or mud, a heavy trunk,

like that of the *Ichthyosaurus*, would immediately subside therein back downwards, while the broken tail, supported by its flat surface, would afterwards be dragged down at an angle with the trunk, and with its extremity directed towards the ventral—now, as when the body floated, the uppermost side of the body: this is, in fact, the position in which the broken part of the tail is generally placed in the fossil skeletons.

The prevailing amount of dislocation which most of the skeletons of the *Ichthyosauri* present, is exactly such as might be conceived to take place in a dead animal body buoyed up sufficiently long to allow of a partial separation of the connecting ligaments and cartilages; the probable toughness of the integuments of the Enaliosaurians would tend to retain the gases generated by putrefaction sufficiently long to enable this extent of decomposition to take place while the animal floated, at least in regard to the ribs and bones of the pectoral and pelvic arches. The bones of the paddles on the contrary, and those of the tail, being connected together by denser ligaments and surrounded by a less proportion of soft animal matter, would be more likely to sink comparatively undisturbed, with the rest of the trunk, when the buoyant gases were ultimately set free.

The dead carcasses of the *Ichthyosauri* would of course be subject to such dislocations and separations as the attacks of predatory animals on a floating dead body would produce; but the appearance in the tail of the *Ichthyosaurus* here alluded to, is too uniform and common to be due entirely to an accidental and extrinsic cause. I am therefore disposed to attribute it to an influence connected with some structure of the recent animal; and most probably to the presence of a terminal tegumentary and ligamentous caudal fin, which, either by its weight, or by the force of the waves beating upon its extended surface, or by the action of predatory animals of strength sufficient to tug at without tearing it off, might, under the circumstances already mentioned, give rise to a dislocation of the caudal vertebræ immediately proximal of its attachment. We have evidence, however, in the form of the vertebræ that the supposed fin was not a horizontal one, and I have already observed that the superaddition of posterior paddles in these air-breathing marine animals is the compensation for the absence of such an organ; and, therefore, a tegumentary fin, if developed at the extremity of the tail, would probably be placed in the position best adapted to produce with rapidity those lateral movements of the head most needed in a short-necked predatory aquatic animal.

Since the preceding notes were written and read to the Society, I have had the opportunity of detaching some of the terminal caudal vertebræ of an *Ichthyosaurus communis* from the substance in which they were imbedded;

and have received, through the kindness of Sir Philip Grey Egerton, a separate terminal caudal vertebra of an *Ichthyosaurus* from Lyme Regis, all of which exhibit a compressed form nearly as well marked, in comparison to the vertebræ of the rest of the spine, as is the depressed form in the terminal vertebræ of the *Cetacea*. This structure offers additional and very satisfactory proof of the existence of a caudal tegumentary fin expanded in the vertical direction. Such a fin would be especially useful in the short- and stiff-necked Ichthyosaur; while in the Plesiosaur, where the length and structure of the neck are so favourable for rapid lateral inflections of the head, an instrument like that which produces the corresponding movements in fishes would be unnecessary. Now, it is an interesting fact, that in all those skeletons of Plesiosaurs in which the tail is perfect, it is straight; and there is no indication of the partial fracture or bend in them, which is so common in the tails of the Ichthyosaurs.

March 18th, 1838.

XXXVII.—*A Description of a Specimen of the* Plesiosaurus Macrocephalus, Conybeare, *in the Collection of* Viscount Cole, M.P., D.C.L., F.G.S., &c.

By RICHARD OWEN, Esq., F.R.S., F.G.S., Hunterian Professor to the Royal College of Surgeons, London.

Plates XLIII., XLIV., XLV.

[Read April 4th, 1838.]

LORD COLE having done me the honour to transmit to me for description, his unique specimen of the *Plesiosaurus macrocephalus*, I have endeavoured to devote to it an examination equivalent in care and detail to the admirable completeness of many of its parts, and have reason to hope that it will throw additional light on the Plesiosaurian modifications of the vertebrate skeleton, as well as on some interesting points in general osteology. The study of the spinal column has induced me to reconsider the views generally adopted as to the composition of a vertebra; and I have found it convenient, if not absolutely requisite, to give new names, applicable both in the abstract and concrete senses, to some of the component vertebral elements. The chief specific characters are also premised of another Plesiosaur, which, from the completeness of its skeletons in our national and other collections, it seemed most advantageous to adopt as a term of comparison with the present specimen.

The species to which I refer, is that which is described and figured in Mr. Hawkins's memoir on *Ichthyosauri* and *Plesiosauri* *, under the name of *Triatarsostinus*; but as this designation relates to an imperfect state of the tarsus in the right foot, (for a fourth bone is present in the left tarsus of the same specimen, and a second specimen of the same species in Mr. Hawkins's collection exhibits five tarsal bones on each side,) I propose to refer to it under the name of Hawkins's Plesiosaur (*Plesiosaurus Hawkinsii*), as a well-deserved tribute to the indefatigable labour and remarkable skill to which we are indebted for our knowledge of this interesting species. To subsequent figures, as well as to the casts of this beautiful fossil, has been applied the name of *Pl. Dolichodeirus*, which was originally given by Mr. Conybeare to the Plesiosaur in the collection of His Grace the Duke of Buck-

* Plate XXIV.

ingham : but after a comparison of Hawkins's Plesiosaur with the cast of the *Plesiosaurus Dolichodeirus* in the collection of the Geological Society, and with the original remains of a second specimen of the same species in the British Museum, figured in Dr. Buckland's comprehensive and instructive Bridgewater Treatise, I find the following differences :—

The neck, in Hawkins's species, is hardly more than three times the length of the head ; while, in the *Pl. Dolichodeirus* it is four times that length. Mr. Conybeare states that the neck in the Duke of Buckingham's specimen is fully equal in length to the body and tail ; but in Hawkins's Plesiosaur, the length of the neck only, slightly exceeds that of the body or trunk ; and this difference depends both on a difference in the number as well as in the form of the cervical vertebræ.

The cervical vertebræ in the *Pl. Dolichodeirus*, reckoning as such those which supported hatchet-shaped, and not rib-like, lateral appendages, are, according to Mr. Conybeare, thirty-five in number ; while the corresponding vertebræ in Hawkins's Plesiosaur are twenty-nine in number. The cervical vertebræ in the latter are also shorter in proportion to their breadth than are those of the *Pl. Dolichodeirus*. The head in Hawkins's Plesiosaur is relatively longer than in the *Pl. Dolichodeirus*, equalling a tenth part of the total length of the skeleton ; while in the *Pl. Dolichodeirus* it forms, Mr. Conybeare says, less than a thirteenth part of the same.

A more readily appreciable difference is presented in the forms and relative sizes of the ulna and tibia in these nearly allied species. In the *Pl. Dolichodeirus*, the ulna, or posterior of the two bones which succeed the humerus, is as long as the radius ; and its margin next the radius is but slightly concave. In Hawkins's Plesiosaur the ulna is shorter than the radius, broader in proportion to its length, and with a deeper concavity on its inner margin.

In Hawkins's Plesiosaur, the fibula, in regard to its relative length and breadth, and its bent or reniform figure, and particularly with respect to the curvature of its outer margin, deviates in a greater degree than the ulna from the corresponding bone in the *Pl. Dolichodeirus*.

The differential characters afforded by the bones of the fore-arm and leg are the more satisfactory, because, as we shall presently see, the *Plesiosaurus Macrocephalus* again presents different and characteristic forms of the same bones. There are other and slighter differences in the shape of the hatchet-bones, or cervical ribs, of the humerus, and of the femur ; but as the aim of the present paper is restricted to the characters of the skeleton of the *Plesiosaurus Macrocephalus*, my object will be gained if it be admitted that sufficient proof has been adduced of the specific difference between the *Plesiosaurus Dolichodeirus* and the species with which I wish more immediately to compare the *Plesiosaurus Macrocephalus*.

The skeleton of the *Plesiosaurus Macrocephalus* (Pl. XLIII.) now under consideration rests upon its under or ventral surface, with the neck and head bent to the left side, so as to describe, with the rest of the vertebral column, almost a semicircle, indicating the extent to which the living animal must have enjoyed the power of lateral inflections of the neck.

The exposed part of the skeleton gives a view of the upper surface and right side of the head, which is, however, somewhat crushed and mutilated. A similar view is obtained of the cervical vertebræ ; but these are in general perfect, and so turned as gradually to expose more of the dorsal surface at

the root of the neck: and the seventh, eighth, and ninth cervical vertebræ are displaced, and their component parts dislocated, so as to bring into view the upper surface of the bodies.

The dorsal vertebræ are also inclined to the left side, presenting principally their sides to the observer. Dislocation of the component parts of all these vertebræ has taken place to a greater or less degree, but principally in the lumbar and sacral regions.

A great proportion of the caudal vertebræ is lost; and of those that remain, all the apophyses are separated from the bodies.

The fore and hind paddles of the left side are in a beautiful state of preservation. The greater part of the right fore-paddle is also present; but there is no trace of the hind paddle of the corresponding side, excepting the dislocated portions of the pelvic arch to which it was attached. Owing to the position of the skeleton, the structure of both the pectoral and pelvic arches is more or less obscured.

Of the Trunk.

The number of vertebræ, from the atlas to the first caudal inclusive, is fifty-two. They are generally characterised by having a less antero-posterior extent of body, and a greater antero-posterior extent of the spinous process, than in the *Plesiosaurus Hawkinsii*. Those vertebræ, as the seventh, eighth, and ninth cervical, in which I have been able to examine the under-surface of the body, have presented a broad and slightly-produced longitudinal ridge along the middle line; a character, however, which may be observed in a slighter degree in the cervical vertebræ of the *Pl. Hawkinsii*.

In the generic characters afforded by these parts of the skeleton, the vertebræ of the *Plesiosaurus Macrocephalus* correspond with those which Mr. Conybeare has described in the original and admirable memoir* devoted to the determination of this most interesting genus of Enaliosaurs.

Before, however, proceeding to compare the vertebræ of the several regions of the spine in the *Plesiosaurus Macrocephalus* and *Plesiosaurus Hawkinsii*, I would offer a few observations on the composition of a vertebra in the abstract.

At the commencement of my examination of the fossil remains of the Enaliosaurians, I endeavoured to apply to the parts of the vertebræ, (which in these animals are frequently complicated, and with the elements more or less dislocated) the views and nomenclature of M. Geoffroy St. Hilaire, whose analysis

* Geol. Trans., Lond., vol. v., part 2.

of a vertebra in the abstract, has been generally adopted in this country. I was compelled, however, to relinquish the advantage which the vertebral theory of that philosophical anatomist seemed to promise, finding that it did not agree with my observations either on the cartilaginous or osseous centres as they appear in the development of a vertebra in the embryo; or on the fully-developed elements as they are exhibited in different classes of the vertebrate series; more especially in certain parts of the vertebral column of the *Plesiosaurus*.

I need hardly observe that a vertebra may be traced through its various degrees of complication, either in the progressive stages of growth of a complete example, or by taking permanently-formed vertebræ in different animals; or, in many instances, by comparing them in different parts of the spine in the same animal.

The terminal vertebræ of the tail in most species exhibit the simplest condition of these bones. The most complicated vertebræ which I have yet met with are those at the lower part of the neck of a pelican (Pl. XLIV., fig. 3.) and some other birds, or the beginning of the tail of a python (Pl. XLIV., fig. 2.), or other large serpent.

The parts or processes of such a vertebra may be divided into *autogenous*, or those which are independently developed in separate cartilages, and *exogenous*, or those which shoot out as continuations from these independent constituents: the latter are indicated by dotted lines in the diagram, fig. 1., Pl. XLIV. The autogenous, or true elements, are,

1st. The *centrum* or body of the vertebra, which, in Mammalia, as Cuvier has observed, is complicated by two *epiphyses*.

2nd. Two superior laminæ developed to protect the great nervous chord which rests on the upper surface of the centrum, and which I have therefore proposed to call *neurapophyses**. In some Chondropterygians each centrum supports four superior laminæ.

3rd. Two inferior laminæ developed, generally to protect the great blood-vessels on the under surface of the centrum, and which I have proposed to call *hæmapophyses*†.

* They are the *periaux*, or *perivertebral* elements of Geoffroy St. Hilaire.

† These are the chevron bones of Mr. Conybeare, the *paraaux*, or *paravertebral* elements of Geoffroy St. Hilaire;—terms which he also applies to the costal processes,—regarding these as the expanded halves of the chevron bones. If I had adopted Geoffroy's term, "paraal," or its English equivalent, "paravertebral element," I must have diverted it from its original sense, in which it is applicable to two distinct elements, viz. the ribs and chevron bones, which will be seen to co-exist in certain vertebræ of the *Enaliosauri*, and some existing animals; and I have preferred, therefore, to invent and define a new term, which has the advantage of expressing a physiological relation; and I am happy in being able to cite the authority of Cuvier for the propriety of this step. His

4th. The superior spinous process*, which is connected, and generally anchylosed with the distal extremities of the *neurapophyses*, and forms, in conjunction with those processes, the superior arch of the vertebra.

5th. An inferior spinous process†, which is connected and commonly anchylosed with the distal extremities of the *hæmapophyses*, forming, in conjunction with these, a chevron or v-shaped bone.

To the category of *autogenous* vertebral pieces belong the ribs, which generally are anchylosed to the other vertebral elements in the cervical, sacral, and caudal vertebræ of the warm-blooded vertebrate classes.

The propriety of regarding the ribs as vertebral elements is well illustrated in the *Plesiosaurus*, in the cervical, sacral, and caudal vertebræ of which they assume the form of, and have been generally described as, transverse processes, although they are separate bones.

These elements bear the same relation to the centrum and its true transverse processes which the spinous processes do to the neur- and hæm-apophyses, but they are more rarely anchylosed at their central or proximal extremities.

The length which the ribs attain need form no objection to their being regarded as parts of a vertebra, when it is remembered that the spinous processes, both above and below, are in some fishes longer than the longest ribs in the same skeleton.

In the system of M. Geoffroy St. Hilaire the nine elements of a vertebra are completed by reckoning the spines of the dermal skeleton which, in fishes, are intercalated or articulated with the neural and hæmal spines of the true endo-skeleton as essential elements of a vertebra; and the paraaux, or *hæmapophyses*, are described as being developed in length and changed in direction in order to form the vertebral ribs of the thoracic and abdominal regions.

The vertebræ of the Bird and Ophidian, already alluded to, prove that vertebral ribs and inferior laminæ or hæmapophyses may co-exist, and the composition of the spine of the *Plesiosaurus*, especially in the caudal region, well illustrates this fact; for the costal appendages, which are generally anchylosed to the other vertebral elements in the cervical, sacral, and caudal regions of the spine of the warm-blooded vertebrate classes, retain their ori-

words are, in reference to an analogous case, "Donner à un mot connu un sens nouveau est toujours un procédé dangereux, et, si l'on avoit besoin d'exprimer une idée nouvelle, il vaudroit encore mieux inventer un nouveau terme, que d'en détourner ainsi un ancien."—*Mem. du Mus.*, tome ix. p. 123.

* This is regarded by Geoffroy to consist essentially of two lateral moieties, termed *épiaux*, or *epivertebral* elements.

† The hypothesis of Geoffroy necessitates the consideration of this part as being essentially double, forming the *cataaux*, or *catavertebral* elements.

ginal separate condition throughout the vertebral column in the *Plesiosaur*, and pass by such imperceptible gradations from one condition of physiological subserviency to another, that their nature cannot be mistaken when the entire series is viewed in a complete skeleton; although, when viewed in detached vertebræ of the neck or tail, they present the appearance and have been generally described as hatchet-bones or transverse processes.

True *transverse processes* are, however, always exogenous, or mere projections from the centrum or neurapophyses, and are of secondary importance. They are of two kinds, superior and inferior; both are present in the cervical vertebræ in most classes; the inferior transverse processes alone are developed in fishes.

The *oblique*, or *articulating processes*, are also exogenous, and may be developed either from the neurapophyses or the base of the superior spines of the vertebræ.

As in other complicated bones resulting from an association of several osseous pieces, certain elements of a vertebra may be modified in position and proportions so as to perform the ordinary functions of others, which may be atrophied or absent: thus in fishes, the inferior transverse processes are gradually bent downwards, until, in the caudal region, their extremities meet and perform the functions of the hæmapophyses.

The costal processes or ribs are considered by Geoffroy St. Hilaire* to undergo in the Cetacea, a similar change of direction, and also a dislocation from their usual attachments; and to have their distal extremities bent downwards, and anchylosed to a rudimental spine, so as to assume the form and perform the offices of chevron-bones or hæmapophyses; but as the horizontal processes of the caudal vertebræ in the Cetacea (as exemplified in the skeleton of a young *Balæna Antarctica*, fourteen feet in length, which I have lately had the opportunity of examining,) are originally developed from distinct centres, and in distinct cartilages, they appear to me to represent, with the corresponding permanently separate vertebral elements in the *Plesiosaurs*, the true costal appendages of the tail; and the hæmapophyses must, therefore, be regarded as other and different elements of the vertebra. This view is supported by the fact, that the long transverse processes supporting the ribs in the thoracic region of the spine in the same young Whale, have no osseous nuclei developed in them, but are continuous cartilages from the still unossified parts of the centrum. I may observe also, that the hæmapophyses in the young Cetaceans examined by me, exhibit what appears to be their permanent condition in the Enaliosaurians, viz. a want of bony union at their distal extre-

* Mem. du Muséum, ix. p. 118.

mities ; at least I have never yet observed a true chevron-shaped bone, such as results from the anchylosis alluded to, in any skeleton of an Enaliosaurian.

Of the vertebral elements above enumerated, the centrum is the most constant in its existence ; but the neurapophyses and their spines are the most constant in regard to ossification : there is an obvious reason (in the importance of the nervous chord which they are destined to protect), why these parts should be firm when circumstances might forbid the consolidation of the other vertebral elements. Thus, the neurapophyses are cartilaginous in the Lampreys or Petromyzontidæ, while the centrum is gelatinous, and they are the firmest cartilaginous parts of the vertebræ in the higher Chondropterygians.

The neurapophyses and their spines are completely ossified in the Lepidosiren, while the bodies of the vertebræ are represented by a fibro-gelatinous chord. A similar condition appears to have obtained in the fossil *Microdons* and some other osseous fishes, in which the ossified neurapophyses and hæmapophyses have been preserved, while the bodies of the vertebræ are lost.

I now proceed to apply the preceding views of the elementary parts of a vertebra to the exposition of the general characters of the vertebral column in the *Plesiosauri*.

Vertebral Column.

The cervical vertebræ of the *Plesiosauri* generally present the following parts in a separate or unanchylosed state,—the centre, the neurapophyses, and ribs ; and it is interesting to observe, that although, in general, no transverse processes are developed in this region, an analogy with the structure characteristic of this part of the spine in the Crocodile, is maintained in the division of the articular surface for the cervical rib into an upper and lower portion by a horizontal fissure ; which structure is well described and figured by Mr. Conybeare in the *Plesiosaurus Dolichodeirus*.

In *Mammalia* the interspace of the two cervical transverse processes is occupied by the vertebral artery : in birds by the vertebral artery and sympathetic nerve : in the Plesiosaurus it is too inconsiderable to lead us to imagine it to have been subservient to the protection of any important vessel or nerve ; but its existence, besides being referable to the law of adherence to type, may also have had relation to the presence of an interarticular ligament for the purpose of firmly connecting the head of the cervical rib to the body.

As the cervical vertebræ in the genus *Plesiosaurus* approach the dorsal, the inferior part of the costal articulation becomes smaller, and a corresponding increase of surface is afforded by the superior facet, which also gradually rises from the centrum to the neurapophyses, and in the dorsal vertebræ stands

boldly out as a true transverse process from the upper side of the base of each neurapophysis. At the sacral vertebræ, however, the transverse processes subside to the level of the neurapophyses; and, as the caudal vertebræ recede from the trunk, the articular surface, which, as in the neck, represents, or is in the situation of the transverse process, gradually descends and passes from the neurapophysis to the side of the centrum; but it is not divided by the longitudinal groove which characterizes the costal surface in the neck.

This groove is more marked in some than in other species of Plesiosaurus; and I have seen Plesiosaurian vertebræ undoubtedly cervical, in which no trace of it was visible.

The neurapophyses are commonly unanchylosed with the vertebral centres in any part of the spine, and in some instances throughout the cervical, and at the anterior part of the dorsal region, the neurapophyses have appeared to be joined each by an articular surface to the spine above, as they are to the centrum below,—the spines here remaining, apparently throughout life, unanchylosed to the neurapophyses. This condition of the upper vertebral elements is rarely seen in any cold-blooded vertebrate, and never in the warm-blooded classes.

In those parts of the spine, where the vertebræ enjoyed less mobility upon each other than in the neck, the spines become anchylosed to the neurapophyses at an earlier period.

The hæmapophyses co-exist with the ribs or paravertebral elements, in the caudal region of the spine, but they continue throughout life to be unattached by bone, either to the centrum above or to each other below; and here also their spine is not developed, and consequently no true chevron-bone is formed in the *Plesiosauri*. The hæmapophyses are also continued along the inferior surface of a great part of the abdomen, forming there the sternal or abdominal ribs; and just as the neurapophyses are developed in the transverse direction to protect the expanded cerebral masses in the cranial region, so here the hæmapophyses are in like manner elongated transversely, and their spine is introduced and modified to form a third mesial rib-like bar, connecting, however, as usual, the lower or distal extremities of the hæmapophyses, and completing the osseous cincture of the abdominal viscera.

The tail in the *Plesiosauri* is relatively much shorter than in the *Ichthyosauri*, and I have not observed in any example, that partial dislocation which seems to indicate that it supported a fin in the *Ichthyosauri*. There is an obvious reason for the shortness and simplicity of this part of the animal; in the *Plesiosauri*, the length and mobility of the neck renders a special apparatus in the tail for producing the lateral movements of the head unnecessary.

Such is the general character of the spinal column as regards the composition of the vertebræ in the genus *Plesiosaurus*; and consequently so far the *Plesiosaurus Macrocephalus* agrees with the better known species: it also presents the same generic peculiarities in the form of the articular surfaces of the bodies of the vertebræ as are described by Mr. Conybeare in the *Pl. Dolichodeirus*.

I now proceed to describe the specific characters distinguishable in Lord Cole's *Plesiosaurus Macrocephalus*.

Cervical vertebræ. (Pl. XLIV.)

The cervical region of the spine in this species exhibits the prominent character of the genus in its great extension. It is, however, only twice the length of the lower jaw, instead of three times the length of the same part, as in the *Plesiosaurus Hawkinsii*; and this difference, arising from the greater development of the head in the *Macrocephalus*, is associated, Dr. Buckland observes*, with a thicker and stronger character of vertebræ in relation to the greater weight they had to sustain. It includes 29 cervical vertebræ.

In the 20th cervical vertebra of *Plesiosaurus Hawkinsii* the transverse is to the antero-posterior diameter as 4 to 3. In the corresponding vertebra of the *Plesiosaurus Macrocephalus* the transverse is to the antero-posterior diameter very nearly as 2 to 1. The rest of the cervical vertebræ bear a similar ratio to those of the *Plesiosaurus Hawkinsii*; the bodies of the vertebræ therefore in *Plesiosaurus Macrocephalus*, although by no means so flat as in the *Ichthyosauri*, make an evident approach to the characteristic form of the vertebræ in that genus.

Mr. Conybeare has justly remarked how difficult it is to determine the number of the cervical vertebræ in a *Plesiosaur*, owing to the gradual transition in their lateral appendages from the condition of hatchet-shaped laminæ to the ordinary elongated form of ribs.

For the purpose of gaining a point of comparison of the different species of *Plesiosauri*, I would suggest that the vertebra in which the costal articular surface has first entirely left the centrum and passed upon the neurapophysis should be reckoned as the first dorsal. According to this criterion, the number of cervical vertebræ in the *Plesiosaurus Hawkinsii* will amount to 31, while those of *Plesiosaurus Macrocephalus* are 29.

In the *Plesiosaurus Hawkinsii*, the hatchet-shaped processes are converted into styliform ribs at the 29th cervical vertebra; but in the *Plesiosaurus Macrocephalus* they undergo this change of form at the 27th cervical vertebra, and perhaps at the 25th, but this appendage is lost in the skeleton under consideration.

Hence we may conclude that the *Pl. Macrocephalus* has two vertebræ less in the cervical region than the *Plesiosaurus Hawkinsii*, and probably six cervical vertebræ less than the *Pl. Dolichodeirus*, in which Mr. Conybeare states that "the thirty-five anterior vertebræ exhibit these (hatchet) processes distinctly characterized, and are therefore beyond all doubt cervical†."

The articular surfaces for the ribs on the anterior cervical vertebræ of the *Macrocephalus* are relatively larger and have a more regular lozenge shape than in the *Plesiosaurus Hawkinsii*, in which they are elongated in the axis of the vertebra. They are traversed (as mentioned in the general characters of the Plesiosaurian vertebræ) by a longitudinal groove; this gradually sinks from the middle of the depression towards its lower margin, and at length, at the 23rd cervical vertebra, disappears.

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* Bridgewater Treatise, ii. p. 30. † Geological Transactions, i. (Second Series) p. 384.

The depressions above the costal surfaces for the lodgement of the bases of the neurapophyses resemble in form those of the *Plesiosaurus Hawkinsii*, but extend further down upon the side of the centrum. They are coextensive with the antero-posterior diameter of the vertebral body, and are bounded by two lines meeting below, at a right angle. The angle formed by the corresponding lines in the *Plesiosaurus Hawkinsii* is more open. The distance between these neurapophyseal pits and the costal pits in the anterior cervical vertebræ, differs in different species of *Plesiosaurus*. In the *Macrocephalus* the interspace is very short, never exceeding half the diameter of the costal pit, even in the most anterior of the cervical vertebræ*. In the *Plesiosaurus Hawkinsii* the interspace is equal to double the diameter of the costal pit in the corresponding vertebræ.

There may also be observed in the *Macrocephalus* an evident tendency in the surface supporting the cervical vertebræ to rise above the level of the centrum: and this is the more interesting, as in a large species of a yet uncharacterized *Plesiosaurus* nearly allied to *Macrocephalus*, (and of which a figure of one of the posterior cervical vertebræ is subjoined) the surface on the centrum and the corresponding surface of the neurapophysis do project, as short transverse processes; and thus approximate to the Crocodilian type.

As the seventh, eighth, and ninth vertebræ happen to be displaced in the present specimen, and their neurapophyses to be dislocated, the form and depth of the articular depressions for the neurapophyses, as well as the canal for the spinal marrow, are thus brought into view. The centrum presents only a plane surface for the spinal chord, the rest of the canal being completed by the neurapophyses laterally, and the expanded base of the spine above. The surface in question is bounded by two lateral curved lines, having their convexities turned towards each other. Immediately below, and external to this surface on each side, are the deep and roughened pits for the attachment of the neurapophyses.

The cervical neurapophyses do not, in any of the *Plesiosaurs*, unite immediately together above the spinal chord and canal, so as to form a continuous bony arch, spanning across that part, but they stand upright from their sockets in the vertebral body, parallel with each other, or only slightly converging at their superior extremities. They terminate above, in young individuals at least, in broad rough articular surfaces parallel with the transverse axis of the vertebræ, but sloping down from behind forwards with a slight sigmoid flexure at an angle of 25° with the longitudinal axis of the vertebra.

In the same way, therefore, as the rib or appendage to the transverse processes is bifurcate at its proximal extremity, in those cases where the two transverse processes are separately developed on each side of the vertebra, and where the rib is joined to both; so here the spinal appendage of the neurapophyses is bifurcate at its proximal extremity, and each fork rests upon the above described oblique articular process of its own side.

We have here an analogy between the lateral or costal and the superior appendages of the vertebral centre which the *Plesiosaurus* alone has hitherto afforded.

But besides the two surfaces developed for these articulations with the neurapophysis, each fork of the spine sends off an articular or oblique process from its anterior and posterior extremity; the articular surface looking obliquely upwards and inwards on the anterior process, and downwards and backwards on the posterior process: and thus the spines are locked together throughout the whole vertebral column with the exception of the terminal vertebræ of the tail.

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* I have not as yet seen any Plesiosaurian cervical vertebræ that resemble those of the *Pl. Macrocephalus* in this character, which is the more applicable and valuable from being presented by the body of the vertebra alone.

In adult individuals of the *Plesiosaurus Macrocephalus*, these separate elements of the superior arch become anchylosed together, as is the case in a great part of the spine in the present specimen.

In a Plesiosaurian cervical vertebra, however, measuring seven inches and a half in vertical extent, and three inches and a half in transverse diameter, in the collection of Mr. Hawkins, I find the neurapophyses distinct both from the spine above and the centrum below. But in other cervical vertebræ of a still larger Plesiosaur in the collection of Lord Cole, not only is the spine anchylosed with the neurapophyses, but these are also confluent with the centrum.

In the dorsal region in the *Plesiosaurus Macrocephalus*, as in the *Pl. Hawkinsii* and *Pl. Dolichodeirus*, the neurapophyses and spines become anchylosed; but the former elements continue separate from the body of the vertebra throughout the vertebral column in the *Macrocephalus*.

The cervical spines in the *Pl. Macrocephalus* differ in form from those of *Plesiosaurus Hawkinsii*, in retaining their breadth or antero-posterior extent throughout the neck; their extremities being, as it were, truncate, with the angles slightly rounded off. The powerful ridge of bone which they thus collectively form, is highly characteristic of this species. The consequence of this structure is a diminution of the spinal interspaces necessary for the vertical inflections of the neck; which interspaces are conspicuously present in the *Plesiosaurus Hawkinsii*, where the end of each cervical spine is, as it were, obliquely cut off at the anterior part, so as to allow the neck to be bent upwards much more extensively than could have been possible in the *Macrocephalus* *. What, however, the latter species thus lost in mobility, it gained in strength, the quality mainly required in relation to the movements of its more bulky head and jaws.

As the powerful neck of the *Pl. Macrocephalus*, however, possessed extensive mobility in the lateral direction, as is indicated by its position in the fossil, the muscles destined for these movements must necessarily have been developed in a corresponding degree; and we find that adequate provision was made for their fixed points of action, in the superior development of the costal processes, as compared with those of *Pl. Hawkinsii*:—these processes present, indeed, throughout a greater part of the neck the characteristic expansion of their distal extremities, which led to their being called hatchet-shaped bones by Mr. Conybeare: but the stem which supports the dilated extremity is proportionally longer in the *Macrocephalus*; and it is only towards the base of the neck that the extremities overlap each other, as in the Crocodile. Dr. Buckland has illustrated this peculiarity by placing side by side the figures of the hatchet bones in the *Pl. Hawkinsii* and *Pl. Macrocephalus*. These cervical ribs assume the true costal form, as before stated, at the 27th vertebra, where they are short and straight; behind this part they progressively increase in length, and become bent towards the sternal region.

The cervical vertebræ gradually increase in all their dimensions, (least so, however, in their antero-posterior extent), as they approach the trunk; but the difference in their size at the two extremities of the neck is less than in the *Plesiosaurus Dolichodeirus*.

Dorsal Vertebræ.

These are characterised, agreeably with the previous definition, by the absence of articular surfaces for the ribs at the sides of the centrum, and by the development of a superior transverse process (exclusively supporting the rib) from the base of each neurapophysis.

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* In the large posterior cervical vertebræ of the Plesiosaurus in Mr. Hawkins's collection, the extremities of the spines are expanded; and the anterior obliquely-truncated surface is flattened.

The number of vertebræ in the present species so characterised is 20 : that of the corresponding vertebræ in the *Plesiosaurus Hawkinsii*, is 23.

The vertebræ thus defined include, besides the ordinary dorsal, those which occupy the situation corresponding to the lumbar or ribless vertebræ in the crocodile ; but there are no vertebræ of the trunk wanting ribs in the genus *Plesiosaurus*, in which structure it approximates the Lacertine Saurians.

The special characteristic of the dorsal vertebræ of *Pl. Macrocephalus*, as compared with *Pl. Hawkinsii*, consists in their being (like the cervical) more flattened in the antero-posterior direction, and more concave at the sides ; in which latter particular they resemble the dorsal vertebræ of the *Pl. Dolichodeirus* more than those of the *Pl. Hawkinsii*.

At the commencement of the dorsal series of vertebræ in the present fossil, the bodies of the vertebræ have been subject to a partial dislocation, and begin, as it were, to slide away from the neurapophyses, until the dislocation becomes complete at the sixteenth vertebra : and the articular depressions for the neurapophyses, and the canal for the spinal chord, are again brought into view.

In the succeeding vertebræ the bodies gradually get into place again. Here the lower margins of the neurapophyses begin to lose their angular form, and become rounded off, the articular depressions presenting a corresponding figure. The transverse processes progressively increase in length towards the middle of the trunk, and again diminish as they approach the tail : the bases of the neurapophyses from which they rise diminish in vertical extent in the same ratio, and leave a greater proportion of the centrum free from their embrace. The increasing length and upward inclination of the transverse processes supporting the ribs, Mr. Conybeare has justly observed, " seem intended to give a wider sweep to the ribs," and relates to the acquisition of greater expansion of the *thoracic-abdominal* cavity, where the largest viscera were lodged.

The spinous processes at the beginning of the dorsal region diminish in antero-posterior extent, but slightly increase in height : they then increase in both directions to the middle of the back, and afterwards gradually decrease to the tail.

Sacral Vertebræ.

There are no sacral vertebræ by anchylosis in the *Plesiosauri*. In the present specimen, the dislocated state of the pelvic bones and corresponding region of the spine, renders it difficult to determine against which of the costal processes of the vertebræ the extremities of the iliac bones may have abutted.

In a specimen of the trunk of a *Plesiosaurus Hawkinsii* in the British Museum*, the two sacral vertebræ are distinguishable by the sudden increase in the breadth of their costal processes, as compared with those immediately preceding and succeeding them.

The short sacral ribs in the crocodile present this character in a still greater degree, (as might be expected from its terrestrial habits) ; but we may perceive in the Plesiosaur an evident additional affinity to the Emydo-Saurians, as compared with the Ichthyosaur. The sacral vertebræ of the *Plesiosaurus Hawkinsii* also differ from the lumbar and dorsal vertebræ preceding them by

* See Plate XXV., Hawkins's Memoir on Ichthyosauri, &c.

a small part of the costal articular surfaces being contributed by the centrum; these surfaces beginning to sink down again upon the bodies of the vertebræ, where the increased breadth of the ribs indicates that they gave attachment to the pelvic arch.

Guided by this character in reference to the *Pl. Macrocephalus*, I find that the costal articular surface begins to descend upon the vertebral body at the fiftieth vertebra (counting from the atlas), and consequently reckon this and the succeeding vertebræ as *sacral*; and their relative position to the dislocated ilium verifies the supposition that the same character, with reference to the costal articular surface, points out the bodies of the sacral vertebræ in the *Pl. Macrocephalus*, as it does those of the *Pl. Hawkinsii*.

It is at this part of the vertebral column, in Lord Cole's specimen, that the separation of the vertebral elements from each other, and the displacement of the bodies, again bring into view the surface which supported the spinal marrow, and the articular depressions for the neurapophyses on each side.

The surface which supported the spinal marrow is small and flattened, slightly impressed, bounded by two gently-curved lines, whose convexities are turned towards each other.

A comparison of the medullary canal at this part and at the cervical region, shows that the usual law of the increase of the spinal chord at the parts where large nerves were required to be given off to supply the locomotive extremities obtained in the extinct Enaliosaurians, as in their existing congeners.

The spinous processes are locked together by double oblique articulating surfaces, as described in the cervical vertebræ.

Of the Tail.

Of the tail, there remain in the present specimen the bodies of eight vertebræ, with a few of the caudal ribs and hæmapophyses. From their position, and the decreasing size of the vertebræ, we may safely judge that the tail had the usual proportions observable in other species of *Plesiosaurus*.

Each of these centres presents on its upper surface the continuation of the spinal canal, bounded by two lateral curved lines, with their convexities turned towards each other; and on each side of the canal a roughened subtriquetral surface for the attachment of the base of the neurapophyses. Below this, on each side of the body, there is a rounded pit for the articulation of the caudal rib.

These differ from the costal pits in the cervical vertebræ, in not being traversed by a groove.

The inferior surface of the centrum presents a slightly concave, transversely oval surface, without any longitudinal ridge; and on each side of the anterior and posterior margins there is a half-articular surface, designed to form, in apposition with the adjoining vertebræ, a point of attachment for the hæmapophyses.

The length of that which appears to be the eighth caudal vertebra, is, to its transverse diameter, as 2 to 5.

In the *Pl. Hawkinsii*, I find that the rib has left the neurapophysis, and slid down wholly upon the centrum at the sixty-first vertebra.

In a very perfect tail of a Plesiosaur in Mr. Hawkins's collection, the hæmapophyses are developed beneath the twenty-eight terminal caudal vertebræ, the two or three last small ones only excepted. The bodies of these small terminal caudal vertebræ also present an interesting modification of the surfaces by which they are attached to one another, and if found detached, would

hardly be recognised as belonging to the genus *Plesiosaurus*: they are hollowed out like the vertebræ of the *Ichthyosauri*, so as to join by double concave surfaces, (as shown in the figure (Pl. XLIV., fig. 6.) of the joints between the twenty-seventh, twenty-eighth, twenty-ninth, and thirtieth caudal vertebræ of the skeleton of the *Plesiosaurus Hawkinsii* in the British Museum).

It is interesting to perceive that those vertebræ which are most remote from the centre and source of vital energy, present throughout life a lower and earlier type of structure; such as, from the analogy of the Batrachia, we may assume to have been the fœtal condition of all the other vertebræ.

It is equally interesting to perceive the designed arrest of development at a part of the spine where the elasticity and flexibility retained by that arrest are required for its peculiar functions*.

In conformity with the usual course of anatomical descriptions, we have next to consider the bony hoops which encompass the visceral or thoracic-abdominal cavity, and which consist of two parts, called the vertebral and sternal ribs, although these are, in fact, respectively analogous to the costal processes and hæmapophyses in the caudal region of the spine, and ought strictly to have been considered as parts of the dorsal vertebræ. The vertebral ribs are evidently but prolonged developments of the osseous appendages of the transverse processes of the vertebræ, which we have already seen to exist in the cervical, sacral, and caudal regions of the spine. They begin from the thirtieth cervical vertebra rapidly to increase in length and strength to near the middle of the abdomen, and then more gradually diminish, and

* The caudal hæmapophyses have been hitherto described as *chevron bones* in the *Plesiosaurus*; but in all the specimens and casts which I have examined, they have presented the condition of two appendages distinct from one another. In the *Pl. Dolichodeirus* at the British Museum, the tail rests upon its inferior surface, and the broken spines and costal appendages are alone brought into view. In the cast of the Duke of Buckingham's specimen, in the Museum of the Geological Society, the only parts resembling chevron bones are the detached neurapophyses, or superior arches. In Plate XXV. of *Pl. Hawkinsii*, in Hawkins's Memoir, the small chevron-shaped bone below the fourteenth caudal vertebra, does not belong, as might at first sight be supposed, to the under surface of that vertebra, but is the superior arch of the small, displaced vertebra behind it. The true condition of the hæmapophyses in the *Plesiosaurus* is beautifully shown at the sixteenth caudal vertebra of the *Pl. Hawkinsii* in the British Museum.—(See Plate XXIV. of Hawkins's Memoir.) The hæmapophyses are longer and slenderer than the costal processes; they slightly taper to their distal extremities, which approach each other by a gentle curve, and were doubtless connected together in the recent state by a cartilaginous or ligamentous substance. In the newly-born whale, the hæmapophyses present the same condition, which, however, is a transitory one in this warm-blooded marine animal, in which ossification proceeds to blend the hæmapophyses into a single chevron.

assume the character of detached transverse processes as they approach the tail.

In general form and size, the ribs of *Pl. Macrocephalus* resemble those of *Pl. Hawkinsii*; but they seem (in comparison with Hawkins's fig. 25) to be more suddenly expanded at their upper extremities; and the anterior ribs here present a bilobed appearance.

The articular surface at the proximal or vertebral extremity of the longest ribs (which are about nine in number) is oblong, convex, and roughened for the attachment of cartilage.

Counting from the costal appendages, which change the hatchet-shape for the true rib-like form, to the sacral vertebræ, there are twenty-two pairs of dorsal and lumbar ribs in the *Pl. Macrocephalus*.

The sternal ribs, or abdominal hæmapophyses, in the present fossil, are partially brought into view on the left side of the abdomen: they seem to be relatively slenderer than in the *Pl. Hawkinsii*, and are consequently more like those of the *Pl. Dolichodeirus*; as in both these species they are connected by an intervening mesial, transverse, sternal bone, of a rib-like form, but pointed at both extremities. This is the representative of the hæmapophyseal spine, which is here, in relation to the expansion of the abdominal cavity, developed in breadth or transversely, instead of longitudinally or vertically, as in the tail of fishes.

Pectoral Extremity.

Of the bones composing the sterno-clavicular arch, we easily recognise the broad, expanded coracoid, of which the humeral or articular extremity is seen projecting on the left side of the fossil.

This extremity is relatively broader than in the *Pl. Hawkinsii*, being adapted to a broader joint at the corresponding extremity of the humerus. The notch above the articulation, which receives the humeral end of the clavicle, is shallower than in the *Pl. Hawkinsii*.

The rest of the apparatus is too imperfect to allow of an accurate comparison being carried further.

In the bones of the paddle, or radiated appendage of the pectoral arch, the following differences exist between the *Pl. Macrocephalus* and *Pl. Hawkinsii*.

The humerus is (as has been just observed) less contracted at its proximal extremity: it is altogether less curved backwards, the anterior margin being concave instead of straight or convex, as in *Pl. Hawkinsii*. The distal end terminates in a slight but regular convex curve; while in the *Pl. Hawkinsii* the separate facets for the radius and ulna are distinctly marked, and meet so as almost to form an obtuse angle.

In the *Plesiosaurs* generally the *radius* is nearly straight, while the *ulna* is bent, with the concavity towards the radius; both bones are flattened, as in the other Enaliosaurians. In *Pl. Macrocephalus* the margin of the *radius* next the *ulna* is more concave than in *Pl. Hawkinsii*, and the bone is relatively broader at its distal extremity, which is terminated by a convex instead of a nearly straight line.

The *ulna* equals in length the *radius*, as in the *Pl. Dolichodeirus*, while it never attains the same length in the *Pl. Hawkinsii*. It is, in the *Macrocephalus*, relatively broader than in either the *Pl. Dolichodeirus* or *Hawkinsii*. It also presents a more complete reniform figure; the humeral articular surface not being so straight, or so distinctly marked off from the outer convex margin.

The *carpus* consists, in *Pl. Macrocephalus*, of eight, instead of, as in *Pl. Hawkinsii*, six ossicles. The fourth, or additional one in the first or proximal row, is wedged in between the ulna and the third carpal bone, at the outer angle of the carpal joint; it is much smaller than the rest.

The relative sizes, also, of the three normal bones of the first row is different. In the *Pl. Hawkinsii* the middle one is the largest; the radial, or anterior one, the least. In the *Pl. Macrocephalus* the ulnar, or posterior of the three, the largest.

The disproportionate size of the two posterior bones in the *Pl. Hawkinsii* compensates for the shortness of the ulna. In the distal row of the carpus the superadded bone in the *Pl. Macrocephalus* is a very small ossicle wedged in between the third or posterior carpal, and the fifth or ulnar metacarpal bones.

The metacarpal bones correspond with those of the *Pl. Hawkinsii*; the radial or anterior one which represents the pollex being the shortest and broadest.

	Pl. Macroceph.	*Pl. Hawks.*
The first metacarpal supports	2 (but probably 3) phalanges	3
The second metacarpal	6	6 or 7.
The third ditto	9	8 or 9.
The fourth ditto	8	8
The fifth ditto	6	6*

The evidently natural curve formed by the distal phalanges in Lord Cole's *Pl. Macrocephalus* indicates that the paddles had a greater flexibility of this tapering extremity than those of the Cetacea possess.

Pelvic Extremity.

Of the bones composing the pelvic arch, the outer convex margins of the two pubic bones, small portions of the two ischia, and the femoral extremity of the left ilium are visible. They show that the general form and relative proportions of these bones correspond with those of the better known species of Plesiosaurus.

There is, however, an evident difference in the proportion of the length of the pubis to that of the vertebral column. We have enough of the pubis to ascertain that its length somewhat exceeded the length of four of the lumbar vertebræ; while in *Pl. Hawkinsii*, the length, or antero-posterior diameter of the pubis is only equal to three and a half of the lumbar vertebræ: and this difference evidently does not altogether depend on a smaller antero-posterior diameter of the vertebræ in the *Pl. Macrocephalus*, but in a greater development of the pubis, which is in relation to the greater size of the hinder paddle in this species.

The femur in the *Plesiosaurus Macrocephalus* is relatively longer than in *Pl. Hawkinsii*. In the latter it equals the humerus in length; in the former it exceeds the same bone by one-eighth of its own length.

In the *Pl. Macrocephalus* it is rather more expanded at the distal extremity than in the *Pl. Hawkinsii*; but the difference of form is not so well marked as in the humeri of these two species.

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* In the enumeration of the Phalangeal bones by Mr. Conybeare (Geological Transactions, i. p. 387.) the metacarpals are included; the perfect digits of the *Pl. Dolichodeirus* correspond in number with *Pl. Hawkinsii* and *Pl. Macrocephalus*.

The bones of the leg have the same distinguishing character as those of the fore-arm, and the *fibula* in all the Plesiosaurs corresponds to the *ulna* in its peculiar bent figure.

In the *Pl. Macrocephalus* the fibula is, however, relatively broader than in the *Pl. Hawkinsii*, notwithstanding that, like the ulna in the fore-arm its distal extremity is on the same plane with that of the adjoining bone: it is, in fact, fully as broad as it is long, which proportions, combined with the characters of the cervical vertebræ, distinguish it from the fibula of any other species of *Plesiosaurus* which I have yet seen.

The tarsus consists, in *Pl. Macrocephalus*, of six instead of five bones, as in the *Pl. Hawkinsii*; it participates in the peculiarity of having three bones which are situated at the anterior, or tibial side of the joint, much smaller than are those of the fibular side, and so placed, in the intervening space between the tibia and tibial metatarsals as to indicate that the foot had a freer inflection forwards, or upon the tibia, than in the opposite direction.

This structure, Dr. Buckland has observed to me, would give a compound motion to the propelling stroke of the paddle, similar to that which in skilful rowing is called feathering the oar.

In the *Pl. Hawkinsii* the interspace between the tibia and metatarsals is occupied by a single round and flat bone; in the *Pl. Macrocephalus* by two; the additional bone being situated at this part of the tarsus.

The metatarsals resemble, in number and disposition, those of the *Pl. Hawkinsii*, as is shown in the following table:

	Pl. Macroceph.	*Pl. Hawks.*
The first, or tibial metatarsal supports	3 phalanges	3
The second	5	5
The third	8 (or 9 ?)	8
The fourth, more than	7	8
The fifth	6	6

In general form and proportions of the phalanges of both extremities, a close resemblance subsists between the two species.

Of the Head. (Pl. XLV.)

I have reserved for the conclusion of the present paper the description of this, the most complicated and difficult part of the skeleton. The relative size of the skull to the body and cervical portion of the spine in the *Plesiosaurus Macrocephalus* has already been stated; but its structure and composition still remain to be spoken of. From its position in the specimen, the composition of the upper and lateral parts only can be examined, but the bones on these surfaces are well defined, and in tolerably perfect condition.

The general form of the head is depressed and triangular as in the other Plesiosaurs; but the breadth of the base of the triangle formed by the posterior part of the head is relatively greater than in the *Pl. Hawkinsii*.

The elongated form of the strong and prominent cranial bones, most of which are seen extending from point to point, with wide interspaces, like the timbers of a scaffolding, indicates the affinity of the Plesiosaur to the Lacertine Saurians, and this affinity will be further exemplified in the condition of many of the individual bones.

The only parts of the occipital bone visible in the present head are the superior extremity of the supra-occipital, where it is joined to the posterior point of the bifurcation of the parietal, and the point of the right lateral or exoccipital, where it abuts against the suture between the transverse process or fork of the parietal and the tympanic bone.

The force which has crushed the head has fractured the parietal just at its point of bifurcation, and the strong transverse forks are separated from each other and from the median or ordinary part of the parietal from which they were continued; these fractures are also accompanied with a slight dislocation of the respective parts. The natural form of the parietal bone in the Plesiosaurus is, however, well displayed in the head figured by Mr. Conybeare, in the 2nd vol. of the 2nd Series of the Society's Transactions, (Pl. XIX. fig. 2.); and the oblique sigmoid suture uniting the extremity of the parietal process to the tympanic bone is also indicated in that figure at about half an inch from the point of bifurcation. In the *Pl. Macrocephalus* the transverse processes of the parietal are relatively stouter and longer than in the Plesiosaur there figured, or in the *Pl. Hawkinsii*. That on the right side in the present specimen forms the most prominent part of the bones of the head. The normal portion of the parietal bone, anterior to the bifurcation, presents a distinct division into two lateral moieties by a sagittal suture. The sides of this suture, or rather harmonia, for it is not denticulated, are deep, being formed by the apposition of two ridges of bone which rise and meet to form the longitudinal intermuscular crest which traverses the middle line of the upper surface of the head in this, as in other species of Plesiosaur. Two inches anterior to the bifurcation of the parietal the foramen which characterizes the parietal in many Lacertine Sauria is plainly indicated by the moiety of its circumference which is due to the left parietal ridge, which alone is here preserved. The long diameter of this vascular foramen is three lines.

The coronal suture seems here to divide the parietals from the frontals immediately anterior to the above foramen, which thus belongs entirely to the parietals, as in the genera *Monitor*, *Lacerta* proper, and others; while in the *Ichthyosaurus* the corresponding foramen is placed directly upon the coronal suture, as in the genera *Iguana* and *Stellio*.

The parietals slope away immediately from the median ridge, indicating the extent of the strong temporal muscles which were only separated on the top of the head by the thickness of this ridge. In this structure we find the *Plesiosaurus* resembling the lacertine *Iguana* among existing Saurians, and differing from the Crocodiles and Gavials, which have the temporal muscles

separated by a flattened interspace of the parietal bone. The Plesiosaurs present a still more marked affinity with the Squammate Saurians, and deviation from the Loricate tribe, in the posterior bifurcation and median foramen of the os parietale.

The general condition of the present fossil indicates it to belong to a young individual, and to this circumstance may be attributed the non-consolidation of the two parietals into a single median bone, as is its condition in all other Saurians.

The median frontals extend forward as far as the midspace between the small nostrils, and appear in the *Pl. Macrocephalus* to terminate in a point between the commencement of the narrow nasal bones. The interfrontal suture is elevated by a ridge continued forwards from that of the interparietal. The outer margin of the median frontal forms the superior boundary of the orbit. The anterior frontal enters into the formation of the anterior and superior angle of the orbit, and is wedged in between the mid-frontal and superior maxillary bones. The posterior frontal, which is here narrower than in the *Pl. Hawkinsii*, resembles the columnar portion of the corresponding bone in the Crocodile, which bounds the orbit posteriorly and extends downwards to join the malar bone; but this bone is more superficially situated in the *Plesiosaurs*, which thus resemble more the Lacertine Saurians.. The affinity of the Plesiosaurs to this group and their recedence from the Crocodilian type is more strikingly evinced in the non-extension of the posterior frontal to join the mastoid, and the consequent absence of the osseous ridge which traverses longitudinally the temporal fossa like a second zygoma, and peculiarly characterizes the cranium of the Loricated Saurians.

The zygomatic portion of the temporal also resembles the Lacertine and deviates from the Crocodilian type in its elongated form and horizontal longitudinal position. The inner surface of this bone is seen on the left side of the head, while only that part which joins the malar and posterior frontal remains on the right side in the present specimen. The tympanic bone, in its general form and especially its length, is intermediate to the Crocodilian and Lacertine types; while in regard to its strength it exceeds that of all existing Saurians. The expanded inferior termination of this important bone, which gives the surface of articulation to the lower jaw, appears in the present specimen to be formed by a distinct osseous piece or epiphysis, but the difficulty of discriminating between suture and fracture in a crushed fossil leaves me in some uncertainty regarding this point: I may observe, however, that a supplementary bone, but of much smaller size, occupies a corresponding situation in the cranium of the Monitor.

From what can be discerned of the structure of the posterior part of the skull in the present specimen, and from the appearance of the lias-matrix which has intruded beneath the tympanic arch, on the right side, into the temporal fossæ, there is sufficient evidence that, in the *Pl. Macrocephalus*, a large opening on each side of the occipital region of the cranium leads beneath the parieto-tympanic arches into the temporal fossæ. This conformation differs from that which is expressed in the posterior view of the restored head of the Plesiosaur, given by Mr. Hawkins in the 23rd Plate of his Memoir; but repeated and close examination of the skull, both of Lord Cole's specimen and of the *Pl. Hawkinsii*, prove that the Plesiosaurus participated in the Lacertine type of cranial structure and deviated from the Crocodilian *, in the presence of the openings above described.

When we come to consider the facial and maxillary bones, the correspondence with the Lacertine Sauria begins to diminish, and that with the Crocodiles to increase. This tendency to the higher type of Saurian organization is shown in the strength of the whole maxillary apparatus, in the great relative size of the intermaxillaries, the roughened exterior surface, and the distinct alveolar cavities for the teeth. But the nostrils, in their size and position, combine with the structure of the paddles to indicate the affinity of the extinct Enaliosaurs to the existing Cetaceans, and offer a beautiful example of the adaptation of structure to the peculiar exigencies of a species.

The apertures through which the air is respired are placed, in the *Pl. Macrocephalus*, exactly where Mr. Conybeare has described them to be situated in the *Dolichodeirus*, and where they are placed in the *Pl. Hawkinsii*, viz. a little anterior to the orbits, near the highest part of the head. In the present specimen it would seem that the intermaxillaries formed no part of the boundary of the nasal apertures, while in the Crocodiles almost their entire circumference is due to these bones. The nostrils in the Plesiosaur are formed by an interspace at the convergence of the anterior frontal, nasal, and superior maxillary bones. In the Lacertine Saurians, a small proportion at least of the boundaries of the anterior nostrils is always formed by the intermaxillaries, and these orifices are separated by a bony longitudinal partition, as in the Plesiosaur. The intermaxillary suture extends from the anterior part of the nostril forwards to a little more than half-way between the orbit and anterior extremity of the cranium. One of the strongest of the inferior teeth rises just in front of this suture, and a slight notch at that part seems to

* This communication is reduced to a very small opening in the Crocodiles in consequence of the form and position of the os tympanicum.

correspond with that tooth, and offers a resemblance to a very characteristic structure in the true Crocodiles. The lachrymal bone forms a great proportion of the anterior and inferior part of the orbit: the superior maxillary appears to form a small part of the orbital circumference below the lachrymal, and the malar bone rests by an oblique suture upon its posterior extremity; the posterior margin of the malar is joined to the posterior frontal, thus completing the posterior osseous boundary of the orbit, and to the zygomatic, or temporal bone.

The concave articular surface of the lower jaw is well displayed in Lord Cole's specimen, indicating free and frequent motion of that bone; the posterior process of the angle of the jaw closely resembles that of the Crocodile. The suture between the angular and supra-angular or coronoid process is well displayed, showing the same complicated structure of the lower jaw which Messrs. Conybeare and De la Beche have so admirably illustrated in the allied genus *Ichthyosaurus*. The coronoid processes, however, rise higher, and form a sharper edge for the insertion of the temporal muscles than in the Crocodiles; and we have another important indication of affinity to the Lacertine, at the expense of departure from the Crocodilian type, in the absence of the vacuity between the angular and supra-angular pieces, which vacuity peculiarly characterizes the Crocodiles.

The correspondence in the position of the head in the present specimen with that of one of Mr. Hawkins's beautiful specimens of the species which I have dedicated to him, and which he has obligingly permitted me to delineate (Pl. XLV.), enables me to state that, in the *Pl. Macrocephalus*, the maxillary portion of the cranium is relatively larger, as compared with the cranial portion, than in the *Pl. Hawkinsii*; that the orbit is nearer the back part of the cranium, and the temporal fossa consequently shorter; and that the tympanic arches, upon which play the branches of the lower jaw, are relatively much stronger.

In all these points, as also in the relative size of the head to the trunk, and in the shorter but stronger neck, we perceive the most admirable illustrations of the laws of organic co-existence; and at the same time are enabled to trace a closer affinity, in the present species, than in any other hitherto described, to the Crocodilian and Ichthyosaurian types of structure.

XXXVIII.—*On the Fossils of the Eastern Portion of the Great Basaltic District of India.*

By JOHN G. MALCOLMSON, Esq., F.G.S.

[Read November 15 and December 6, 1837.]

Illustrations, Plates XLVI. to XLVII.

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Introduction.

THE principal objects of the following paper are, to submit to the Society an account of a series of fossils discovered in the eastern part of the great basaltic district of India; and to endeavour to arrive at some approximate conclusion respecting the geological era of this basaltic formation, which, extending over more than 200,000 square miles, conceals, breaks up, or alters all the other rocks from beneath which it has forced its way. Of the eruptions to which this rich and romantic country (formerly including several considerable kingdoms) owes its existing form, a late President of this Society remarks*, that the mind is almost lost in the contemplation "of their grandeur;" but "that unfortunately the relative age of the eruptions must remain for the present undetermined, no vestiges of secondary or tertiary formations having been detected within the region." Having therefore, in 1832, collected a series of lacustrine fossils, probably referable to the tertiary epoch, from a portion of

* See Mr. Murchison's Anniversary Address, Geological Proceedings, vol. i. p. 454.

this district extending 140 miles north and south, and having procured others from localities to the north and west of that which furnished my own collection, I am induced to submit the specimens to the Society*. If they should be deemed of sufficient value, I wish a selection to be deposited in the museum, to afford a means of comparison with a duplicate set, which I shall forward to the Asiatic Society of Bengal†.

But it is not alone by supplying some data from which to infer the relative age of the great trap formation, that these specimens are valuable. They will afford the means of connecting the great sandstone formations of the south and north of India, containing the celebrated diamond mines of Parteal (Golcondah,) Bangnapilly, and Panna, as well as the limestones and schists associated with them; and which, from the latitude of Madras to the banks of the Ganges, exhibit the same characters, and are broken up or elevated by granite or trap rocks, in no respect differing in mineralogical characters or geological relations. A few remarks on these formations, and the physical geography of the countries in which they occur, will be a necessary introduction to a more particular account of that portion of the trap district in which the fossils were found, Mr. Calder's sketch not being sufficiently detailed, and the map attached to his memoir containing some errors of material importance‡.

General Sketch of the Physical Features, Hydrography, &c.

An elevated tract to the north-west of Bundlecund (not included within the range of the Map, Pl. XLVI.) may be considered as the geological connexion between the provinces watered by the southern branches of the Ganges and the Deckan, including all the countries to the south of the Nerbudda. From the north of this plateau, which extends far to the west, a number of great rivers descend, by a series of rapids and falls over sandstone escarpments, into the valley of the Jumna and the Ganges. From the east and south of the same tract, the Mahanuddy river collects a great body of water, and after a comparatively short course through countries little known, but containing the diamond mines of Sumblepoor and extensive trap and gneiss formations, empties itself into the Bay of Bengal, not far south of the Delta of the Ganges.

The Nerbudda, which flows in an opposite direction, is more interesting in a political and geological point of view; and the extensive countries through which it passes have been more carefully investigated than any other part of the

* See Plate XLVII., drawn, engraved, and described by Mr. James de Carl Sowerby.

† The series of specimens presented by Mr. Malcolmson to the Geological Society have been arranged in the foreign department of the museum.

‡ Asiatic Researches, vol. xviii.

Peninsula. This river takes its rise to the west of Amerkantack, and traversing a country of granite, sandstone, and basalt, abounding in iron and the finest dolomitic marbles, reaches the Indian Ocean through the alluvial plains of Guzerat. At Jabulpoor and in the neighbourhood of Saugur, fossil mammalia, shells, and silicified palms have been recently discovered. Fossil shells have also been found in some of the trap hills, which have broken up the sandstone near the sources of the Taptee. This river is separated from the Nerbudda by a range of basaltic mountains; and having the same direction as the Nerbudda, its whole course appears to be in the basaltic formation. (See N.W. corner of Map, Pl. XLVI.)

All the other great rivers of the Peninsula, including the Godavery, Kistnah, Pennar, and Cauvary issue from the western Ghàts, from the summits of which the country slopes gradually to the east, except at the extreme south, where the descent to the plains of the Carnatic is considerable and precipitous.

The Godavery (see Map, Pl. XLVI.) rises in the basaltic region described by Colonel Sykes, (Geol. Trans. Vol. IV. pt. 2, 1836) and, greatly increased in size, it enters the granitic table land of the Deckan, and flows at the southern foot of the Sichel Mountains into a sandstone and argillaceous limestone country. This district is similar to that of Bundlecund and Malwa; it also contains diamonds, and has been much broken up by erupted rocks. From the north, the Godavery derives large supplies of water from the great rivers rising south of the Nerbudda and the Taptee, in basaltic tracts, the soil of which being retentive of moisture, the water is everywhere near the surface. From the south it receives only the Munjerah river, which, flowing through arid granitic plains, furnishes but a scanty addition of water, except during the rainy season. Through a pass in the gneiss mountain of Papconduh it enters the plains of the Coromandel coast. In this district the sandstone reappears, at an elevation little above that of the sea; but basaltic hills, several hundred feet in height, in which marine fossils have recently been discovered, exist almost within the delta formed by its sediment.

The Kistnah derives its waters from a number of considerable rivers, rising in the basaltic and gneiss summits of the western Ghàts, which condense the greater part of the clouds carried by the south-west monsoon from the Indian Ocean. Flowing through the territories of the southern Mahrattas, a country covered with a rich basaltic soil, and abounding in schistose limestone, sandstone, granitic rocks, and basalt, it enters the granitic platform of the Deckan, the limits of which in this direction are unknown. The limestones and sandstones, however, soon reappear on descending the river, and extend across to the basin of the Pennar, and as far as the ascent to the granitic plat-

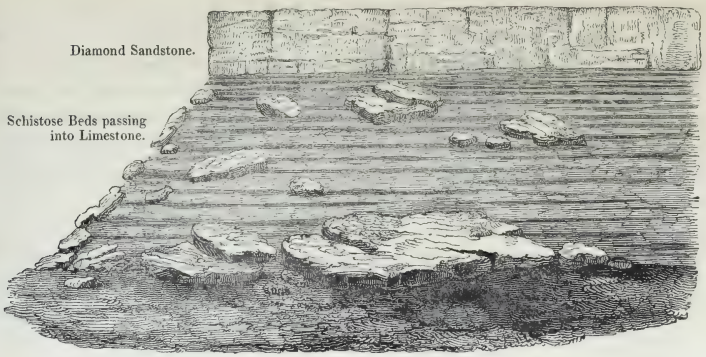
form of the Mysore. It is on the banks of the Kistnah that the richest diamond mines occur, and that the sandstones acquire their greatest elevation, amounting to more than 3000 feet; the river passing through mural precipices of this rock and of the schistose limestones to be presently described. It then enters the plains of the Carnatic, where the same rocks occur, sometimes a little elevated above the level of the sea, at others forming the caps of granite mountains, or broken up by varieties of greenstone and basalt. Thence, passing through a narrow gorge in the gneiss hills of Bezwarrah, it enters the alluvial plains continuous with the delta of the Godavery. Its waters, however, are more loaded with mud than the last-mentioned beautiful river, and the deposit of new land may be seen, by the inspection of a common map, to be proportionably great.

The Pennar is comparatively a small stream, but of much geological interest, the greater part of its waters being derived from the districts in which the diamond sandstones and the argillaceous limestones, on which they rest, are exhibited in their most characteristic forms, and where they are most easily investigated. To describe these strata in detail would be out of place here; but a few of the leading facts must be stated, that the identity of the formations with those of the fossiliferous district, more immediately the object of this paper, may be rendered manifest. Like all the rivers of Southern India, granite is frequently seen in the bed of the Pennar, more especially in its southern branches, where the passes of Ryachottee lead to the granitic table land of Mysore, having an elevation of 3000 feet above the sea, or 2500 above Cuddapah, the principal town of the Pennar basin. With these exceptions, and the occasional appearance of trap through the stratified rocks, the rest of its course, till it approaches the sea, is over rich plains of black and saline alluvium, derived from the decomposition of basalt and of the stratified rocks so often referred to. From these plains numerous table lands, insulated eminences, and ranges of hills, having for the most part a direction nearly N.E. and S.W., rise abruptly, presenting mural precipices of difficult access, around the base of which the roads often make extensive circuits. The Nulla Mulla hills extending from the Mysore frontier to the basins of the Kistnah and Godavery, and the minor ranges dependent on them, and having the same composition and direction, are crossed at right angles by the Pennar, which makes its way through them, like the Kistnah, by traversing narrow gorges with perpendicular sides.

There is not a more remarkable phenomenon in the district watered by the Pennar than the horizontal summits of many of the ranges, and the distinct manner in which the continuity of the strata can be traced from one hill to

another, although extensive plains intervene; while, at no great distance, the sandstone which forms the summits of these hills is seen on the same level as the surrounding plains. Numerous instances also occur in which the original continuity of the horizontal summits is easily traced; the strata on the opposite and nearly perpendicular sides of a valley being similar, but having a considerable dip, the beds descend to the general level of the country. A good example of this is seen, in Section 2, Pl. XLVI., at Chintagoouta and Gundicottah. These anomalies were at first quite inexplicable, nothing appearing in the valleys but a rich alluvium, nor on the summits (which are reached with much difficulty) but a sandstone perfectly horizontal, and divided into huge tables by perpendicular partings, sometimes separated several feet from each other, and filled with broken pieces of the rock. This jointed structure is common to the sandstone, the schistose beds on which it for the most part immediately reposes, and the stratified limestone into which these schists pass insensibly; but the size of the tables so formed, varies from rhombs of a few inches, in the schist and lower part of the sandstone, to enormous masses on the summits of the hills. Nowhere is this structure and the succession of strata, of which it is characteristic, better seen than in the table land in which are situated the celebrated diamond mines of Bangnapilly and others now deserted. The accompanying wood-cut will give some idea of one of these mines.

Table Land of Bangnapilly.



Diamond Mines in Alluvium.

The plains at the base of the table land of Bangnapilly consist of a rich black alluvium, containing fragments of basalt, jasper, and the various minerals found in the hills. It rests on a fine, compact, dark blue or nearly black limestone, which contains much argillaceous and siliceous matter. This limestone

abounds with springs, and is in some places so cavernous as to afford passage to subterranean streams. Basalt protrudes in a few places near Bangnapilly. On ascending the hill, the limestone becomes more schistose, and is of a paler colour, gradually approaching in its structure and composition to clay slate, but it is far more friable. On the schist a more or less compact sandstone rests, varying very much in colour, composition, and appearance in different places. Above Bangnapilly it contains the diamond breccia described by Voysey. As far as the shafts which I had an opportunity of observing, enabled me to judge, the breccia is not an interstratified rock, but an intermixture of the common sandstone, in different parts of the same stratum, with larger fragments of older rocks, generally rounded but sometimes angular. It is not, however, the object of this paper to describe the mines and the interesting district in which they occur further than is necessary to exhibit the type of the formation, by the study of which I was enabled to understand more clearly, the less distinct appearances exhibited by the same rocks, where they have been invaded or buried by the great basaltic eruptions of Central India. On the opposite or west side of the valley, the hill is composed of the same argillo-calcareous formation; but, according to Colonel Cullen, "instead of a sandstone cap, it is crested in its whole length with a sharp black ridge of trap rock, formed of loose blocks piled upon each other, the apparent base of which observed a pretty uniform level, nor is the ridge of much depth. Its extreme narrowness, deep black colour, and the total absence of all traces of vegetation, formed a singular contrast to the rest of the hills, which were covered with long dry grass and scattered bushes*." At a small pass some miles further to the west, the road in ascending, passes over first the dark limestone and a narrow belt of schist, then trap, which is again succeeded by limestone, and the latter by schist, nearly to the summit, "which is capped with a rock of a beautiful flesh colour, with specks and shades of a beautiful green, as if connected with its vicinity to the trap, and of so close and fine a texture as to appear homogeneous even with a lens." "The descent of the pass on the opposite side consists of a clay slate nearly to the foot, where the limestone reappears, and these two rocks continued to alternate with each other to the foot of the second Ghàt, which, like all the former, was composed of clay slate capped with quartzose sandstone†."

The sandstone exhibits many varieties of grain, colour, and hardness: in some places it is white or red, and can be cut into pillars and slabs of great size and beauty; in others it is soft and fri-

* Colonel Cullen, in Transactions of the Literary Society of Madras, January 1837, p. 50. † Ibid.

able, and its inferior beds are not unfrequently schistose, so as to be with difficulty distinguished from the subjacent rock, with which it has in one or two places been observed to alternate. Where the sandstone approaches the great granitic tracts to the south and west, it passes into a compact quartzose rock, as is seen on both sides of the Tripatty Valley. This passage is also observed in other places, as near the Cuddapah diamond mines, where the plentiful occurrence of basaltic pebbles shows the neighbourhood of the trap. Besides the diamond conglomerate, consisting of a great variety of minerals, seams of rock crystal occur, and a fine white quartz containing argentiferous galena, which in former times furnished the country with lead. Specular and micaceous magnetic iron ores, but containing much peroxide, and common iron pyrites, occur with the galena. As far as I have observed, the sandstone always rests conformably on the schists, although from its jointed structure it occasionally, when elevated, appears to meet the subjacent rock at a more or less obtuse angle.

The schists on which the sandstone rests, vary very remarkably in colour, being in different places blue, red, green, or pure white, in which they seem to bear some relation to the incumbent sandstone. They are also occasionally flinty or jaspideous. Sometimes they are wanting, the sandstone resting directly on the limestone, of which the schists are evidently merely the upper beds, and into which they pass insensibly, although it seldom happens that considerable effervescence does not occur on examination by tests. It is in many places impossible to say to which portion of the series any particular specimen belongs.

Voysey has classed the schists with the sandstone under the name of "(the clay slate formation;)" I have, however, preferred to designate the deposit "argillaceous limestone," a term used by him in one of his sections as applicable to the limestone, and which well expresses not only the general character of the rock, but that also of the upper schistose beds.

The limestone is a compact rock, but the strata are usually thin, and are often intersected by vertical partings, a circumstance which frequently limits its use in ornamental architecture. Its most common colour is a light blue, passing into black; but it occasionally occurs of a nearly pure white, and affords an admirable material for basso-relievos. On this stone the finest sculptures of the ruined city of Amrawuty are executed, and for delicacy of workmanship they have perhaps never been surpassed. Were it not for the occurrence of small crystals of quartz, the same quarries would furnish an excellent lithographic stone. Near Cuddapah the dark variety is the common building stone, and many fine columns, caryatides, and cisterns are composed of it. The stone is applied to the same objects in the southern Mahratta country, and along the course of the Godavery towards Nagpoor.

To the south and east of Cuddapah, a narrow valley, nearly 150 miles in length, extends through the limestone, the strata of which are in some places nearly vertical, but form rounded hills. In others they are capped by sandstone, which exhibits mural precipices of much grandeur, and almost or entirely inaccessible. The strata, for the most part, dip to the N.W., resting on the granite of the Carnatic. This rock is penetrated by many dikes of greenstone, which have evidently been instrumental in elevating the stratified rocks to their present singular positions. Little has yet been ascertained regarding the thickness of these strata, which differ much even in the same range of hills. The only minerals they have been ascertained to yield, are varieties of quartz and iron pyrites, the latter of which is so abundant in a few

localities, that sulphur is manufactured from it. At Jumulmudagoo I found the limestone interstratified with muriate of soda; and it is therefore probable, that the salt diffused through the alluvial soil so extensively as to render the water of the Pennar brackish during the hot season, and the inhabitants independent of the sea-coast for a supply of that article, is derived from this source.

On emerging from the gorge in the Nulla Mulla range, the Pennar enters the plains of the Carnatic, and near its mouth flows through low hills of laterite. This deposit rests on the ordinary granite of the Carnatic, with its associated sienites, hornblende schist, quartz rock, and mica slate. It is in a rock composed of a mixture of the last two minerals, that the copper-mines of the Nellore district are situated*. In the same neighbourhood, the sandstone and argillaceous limestones are little elevated above the sea, and are continuous with the same rocks on each side of the Kistnah. They are broken through by insulated basaltic hills, in the neighbourhood of which subterranean sounds and frequent local earthquakes are reported to occur; an assertion I am the more inclined to believe, having myself experienced two slight shocks during a casual visit to the district.

Having briefly described some of the more remarkable phenomena exhibited by the southern portion of the great sandstone and argillaceous limestone formations, it will be unnecessary to enter into any detail when we meet with the same rocks to the north of the Godavery in connexion with the fossil beds discovered in the great basaltic district.

Granite Platform between the Kistnah and Godavery.

(See Map and Section I.)

With regard to the granitic platform of the Deckan, which intervenes between the Kistnah and Godavery, much accurate information is already before the public; it will therefore be necessary only to observe, that it is intersected by numerous greenstone dikes (sometimes of greenstone porphyry), having for the greater part a direction from S. by E. to N. by W., and not very different from that of several of the ranges of basaltic mountains to the north.

These dikes, and the detached masses connected with them, are entirely composed of a crystalline compound of hornblende and felspar, without distinct crystals of augite; and I have never

* The ores are of various kinds, but the richest is a sulphuret, containing, according to Mr. Prinsep, 69 per cent. of the pure metal. The copper also occurs in a slate which Mr. Ouctorlony, of the Madras Engineers, informs me, was considered in Cornwall to be identical with the Killas. If this slate belongs to the "argillaceous limestone" formation, the fact will be of use in determining the relations of that rock to the gneiss, talc slate, and mica schist; a subject on which no observations of any value have yet been made. The primary rocks of this district contain magnetic iron ore and corundum, both of which occur in the diamond sandstone.

detected olivine in them*. The rock shows a tendency to separate into spheres composed of concentric layers and into irregular prisms; and the same structure in some degree occurs in the granite, syenite, pegmatite, &c. of the whole of the south of India. The greenstone is exceedingly hard and difficult to work, but it takes a most beautiful and durable polish, as in the magnificent mausoleums of Golcondah, the tombs of Hyder Alí and Tippoo Sultan, at Seringapatam, and in many of the sculptures of the Carnatic pagodas†. Where these dikes rise into hills, the summits only are composed of the compact greenstone, which graduates below into the granite of the surrounding country. Many of the veins of basalt in the passes of the Mysore and Neilgherry mountains differ from these, in possessing the structure of the compact basalt of Bombay and other places in the trap countries, and in branching into narrow veins, (often not an inch thick,) which traverse the granite without mixing with it; while the ordinary greenstone dikes of the Deckan are almost always accompanied by separate nodules, of greater or less dimensions, insulated in the granitic mass, the component parts of which appeared to me to be there, in most cases, arranged in larger crystals, and to be more subject to decay, than in other places. I could not resist the inference, that, at the time of the formation of these dikes, the granite was in a state approaching to fluidity; although, as some of the narrow veins can be traced for many miles through the granite, they do not appear to have been formed at the same time.

Several small basaltic hills are insulated in the granitic platform in the line of route between Hyderabad and Nirmul, and they are based on decaying granite. Their flat summits and steep sides correspond with the hills of the great trap district; and the general line of bearing, of the broken ranges of which they appear to form a part, does not differ much from that of the basaltic mountains to the north, or from the greenstone dikes; but many hills are scattered over the plains to the east and west, and cross this line of route in every direction. The lower part of the hills is composed of thin tables or laminæ of a sonorous trap, and the upper of globular concentric basalt; the external layers of which are extremely friable, generally grayish, or soft and soapy to the feel, and are of a greenish tint, except where the stone is much loaded with ferruginous grains of a reddish brown colour. In some places the metallic matter has the appearance of having been partially smelted, and is of a fine red hue.

The nuclei of the "concentric basalt," which are exceedingly tough, and resist decomposition powerfully, are of a deep black colour, and contain large crystals of olivine, and small kernels of calcedony. The first of these minerals is not found in the soft external coats, yet it is so closely united with the substance of the rock as not to admit of a doubt of its being of contemporaneous formation, and not, as supposed by Berzelius‡, a fragment of a pre-existing stone enveloped in the liquid matter. Small, but very characteristic specimens of calcedony are of more frequent occurrence in the softer portions of the rock, especially between the concentric nodules; but they are intimately mixed with their substance. It is remarkable, that I detected no calcareous minerals in similar situations in these hills, although the rock is so impregnated with lime as to

* See note to page 575. † It is familiarly known in India as "black granite."

‡ Edinburgh Journal of Science, January 1839.

have led to an extensive deposit of calc-tuff (Kunkur), at present forming along its base, and projecting sometimes half a foot from between the partings of the basaltic tables.—" The presence of olivine, the soft wacké in which the globular basalt is imbedded, the less crystalline structure, the passage into a porous amygdaloid, containing calcedonies, zeolites, &c., and the granite in the neighbourhood of all the smaller masses differing little from that at a distance," may perhaps be sufficient to distinguish these insulated basaltic hills from the greenstone *.

On approaching the Godavery, the granite in some degree changes its appearance, containing large and beautiful crystals of red felspar, occasionally imbedded in veins of transparent quartz, clouded with spots and wavy lines of a turbid milky colour. Greenstone dikes are there more common. The river flows over granite, which is intersected by several dikes of greenstone, running more in a north and south direction than those above referred to, and having many minute white crystals diffused through their substance. The dikes project from 8 to 10 feet above the granite, and are divided into rhomboidal masses by fissures, in which lime is deposited. The bed of the river is covered by numerous fragments of calcedonies, zeolites, and other minerals found in volcanic rocks; and they have been cemented into a more or less solid calcareous conglomerate. The banks are composed of a black basaltic soil, from the lower part of which, where it rests on the granite, as well as from the divisions between the several layers of alluvium, thin slabs of a clayey calc-tuff (Kunkur) project, and are connected above with portions formed round the roots of plants, and below with other layers spread out between the different strata of alluvial earth†. These appearances sufficiently indicate the neighbourhood of the basaltic range of mountains, distinguished in Arrowsmith's large map as the Sichel or Shesha hills, but which are locally known by the name of the Nirmul range, from the large town situated six miles from the difficult pass leading up the steep escarpment presented by their southern face. None of the stratified primary rocks are seen at the foot of these hills in the line of the section; but twenty miles to the east of Nirmul, and a few miles south of the mountains, hornblende slate occurs, resting on granite and quartz rock.

Iron Ore, Mines, and Manufacture of the Steel.—The magnetic iron ore, employed for ages in the manufacture of the Damask steel used by the Persians for sword-blades, is obtained from this schist. The mines I examined, are those of Deemdoortee, but the ore is extensively distributed. The minute grains or scales of iron are diffused in a sandstone-looking gneiss or micaceous schist, passing by insensible degrees into hornblende slate, and sometimes containing amor-

* Journal of the Asiatic Society of Bengal, February 1836, p. 105.

† Further details on this part of the route will be found in some notes explanatory of a collection of specimens presented to the Asiatic Society of Bengal, and published in the Journal of that Institution for February, 1836.

phous masses of quartz. The strata are much broken up and elevated, so that the dip and direction are in no two places the same, and bear no relation to the mountains to the north.

Manufacture, &c.—The mines are mere holes dug through the thin granitic soil, and the ore is detached without difficulty by small iron crow-bars. It is then collected and broken on projecting masses of granite or quartz by means of a conical-shaped fragment of compact greenstone; but when too hard to yield to this simple instrument, it is previously roasted. The sand thus procured is washed in shelving depressions dug near a tank, and the heavier parts, separated by this process, are exactly similar to Voysey's specimens of the iron-sand used in the manufacture of Damascus steel at Kona-Sumoondrum, in the same neighbourhood; but from his published papers, it does not appear that he had seen the rock from which they were derived. In other respects, all the information I could procure, accurately corresponds with that given in his interesting paper*. The ore is then smelted with charcoal in small furnaces, which have often been described. I did not see any flux used; but, although I watched the whole process, from the digging of the ore till it was formed into bars, I will not assert that none was employed. The iron has the remarkable property of being obtained at once in a perfectly tough and malleable state, requiring none of the complicated processes to which English iron must be subjected, previous to its being brought into that state. Mr. Wilkinson, who has investigated the history of Indian steels with much scientific and practical skill, did me the favour to submit to experiment a specimen of this iron as it came from the furnace. He found it to be extremely good and tough, and considered it superior to any English iron, and even to the best descriptions of Swedish. The Persian merchants, who frequent the iron-furnaces of Kona-Sumoondrum, are aware of the superiority of this iron, and informed Dr. Voysey, that in Persia they had in vain endeavoured to imitate the steel formed from it; a failure which could be ascribed only to the difference of the materials used, as the whole process of the conversion into steel was conducted under their own superintendence. It is also probable, that there are few places in India where an ore of equal value is so easily procured; otherwise its distant inland situation, in a difficult and unsettled country, would not have retained a reputation for so many ages. In the manufacture of the best steel three-fifths of this iron is used; the other two-fifths being obtained from the Indoor district, where the ore appears to be a peroxide. It is evident, that if the beautiful water of the Damascus blades is derived from the crystallization of the steel, the use of two very different varieties of iron, one of which has been ascertained to be of such admirable quality, must have an important influence on the appearance and quality of the manufacture.

As these mines afford a boundless supply of ore easily wrought, and are situated in the neighbourhood of vast forests, and near a river navigable for boats during part of the year, it is probable, that at no distant period, when the native government has undergone some amelioration, iron may become an important article of commerce. On this account, and because, although much has been written regarding Indian steel, nothing has yet been brought prominently forward regarding the finer kinds of iron ore with which that country abounds, I will make a few additional observations regarding them.

Dr. Heyne has accurately described the manufacture of iron in the Carnatic, to the south of the Pennar river, and he states that it is, when first smelted, extremely brittle, requiring several operations to bring it into a malleable state. I possess specimens of two varieties of ore used in the district in which he observed the processes, and where I have myself seen them carried on. The one, an iron sand, collected in the beds of rivers, consists of the protoxide, mixed with much of the peroxide; the other, a red schist, is almost entirely composed of red oxide, but in the centre

* Journal of the Asiatic Society of Bengal, vol. i., p. 245.

of the mass it affects the magnet. Not far from where this rock occurs, I collected specimens of hornblende schist, leaving little doubt as to the ores being of the same nature, the former having become altered *in situ*, in the same manner as some of the superficial strata at Deemdoortee are seen to do. I therefore conclude, that the superior quality of the Nirmul iron depends on the ore being a comparatively pure protoxide. It certainly is not dependent on the nature of the fuel, which is much the same in both places*. Captain Herbert, indeed, long ago suggested, that the superiority of the Gwalior iron over that principally worked in the Himalayahs, depended on the former being a magnetic ore, like that of Sweden; but the first accurate information on the subject was communicated by Dr. Royle to Mr. De La Beche, who states†, on the authority of that gentleman, that magnetic iron ore is extensively diffused in hornblende slate in the central range of mountains in India, and that it also occurs in the Himalayahs. This geological position corresponds with that of the Nirmul ore; but the latter does not bear any resemblance, except in its peculiar lustre, to the Menaccanite of Cornwall, to which it is compared by Mr. De La Beche; nor could I detect any titanium in it. With regard to the geological relations of the magnetic iron ore, it is also necessary to observe, that in India it is not confined to the hornblende schist, but is found extensively distributed in the granite and gneiss of the Carnatic and Mysore, in quartz rock near the iron works of Porto Novo; and, as has already been observed, associated with galena in the diamond sandstone of Cuddapah. The discovery of a mineral, so generally confined to the primary rocks, in the great sandstone formation, affords an additional argument in favour of the opinion of those, who consider this rock and the subjacent schists, as equivalents to the older European sedimentary formations, rather than to those of the supermedial order.

Description of the Sichel Hills, and of the Freshwater Shells.

Returning to the line of route, the granite, on approaching to the Sichel hills, becomes softer and decomposes rapidly; and the soil gradually changes to the well-known black basaltic mould, known in India by the name of "cotton ground," and, as usual, it is mixed with calcedonies, zeolites, &c. Amongst these minerals were some fragments of a red colour, and considerable specific gravity, though full of irregular cavities, and so like the slag of an iron furnace, that I considered them to have had that origin, till I discovered a considerable mass of a similar nature protruding from the granite and black soil by which it was covered. Along with these fragments were others of a semivitrified matter, containing small white crystals of felspar, and hardly to be distinguished from a piece of granite fused by Dr. Voysey in the steel furnaces of the neighbouring district. The granite constitutes the surface rock a little further, gradually passing into a black compact basalt, intermixed with many white spots, apparently of felspar. The trap then becomes softer, forming small hills of a cellular amygdaloid, abounding in cavities lined with green

* Iron, which has been ascertained to be superior, for many purposes, to the best German iron, has been recently imported from the western coast of India; but the mines from which it was obtained have not been examined. Captain Jervis, of the Bombay Engineers, however, informs me, that ores, powerfully affecting the magnet, exist in great quantity at Taygoor, a village of the Koncan, not far from the port from which the iron in question was procured.

† Manual of Geology, 3rd Edit., p. 435.

earth, and many of them filled with calcedonies, zeolites, quartz crystals, and, more rarely, calcareous spar, of the same kind as those, so remarkable for their beauty, in the portion of this formation described by Colonel Sykes (Geological Transactions, vol. 4., p. 422*). The crystals also occur in seams, or are diffused through the trap; and in both cases are intimately mixed with its substance. In the bed of a torrent between two of these hillocks, I met with some soft, clayey, schistose fragments, and others of a siliceous character, and of a black bituminous appearance in the centre, containing very perfect specimens of the *Paludina Deccanensis* (Pl. XLVII. fig. 20,) and fragments of other shells to be hereafter described. Those which I examined were converted into calcedony. A laborious research on the hill failed to discover them *in situ*; but about half-way up the escarpment of the principal mountain, which is very steep, and composed of concentric nodular basalt, imbedded in a soft greenish wacké, a narrow band of a singular quartz rock projected about two feet from the surface. It was remarkably scabrous, of various shades of white and red, and had cavities on its surface covered with fine silky crystals. It had every appearance of having been forced into its present situation, when the basalt covered and partially melted the bed to which it belonged. Many fragments of this rock were found below with the shells; and it was again met with, together with the same and other fossils imbedded in basalt, near Hutnoor. The specific gravity of this rock is 2·473, and some of the specimens effervesced feebly in acids, a portion of lime being dissolved; circumstances in which it corresponds with a similar formation found by Voysey, associated with shells, probably of the same kind, at Medcondah (south of the Godavery), an insulated basaltic hill resting on granite, to which I shall have occasion again to refer. The highest summit of the hills, above the locality of the fossils, is conical, but it is capped by a perfectly horizontal stratified rock, the nature of which I could not determine. It is most probably tabular basalt, although that rock is seldom found in similar situations.

Such are the appearances presented on ascending the difficult pass leading up the steep escarpment of the Sichel hills, which form the southern boundary of the eastern portion of the great trap formation of Central India. The hills extend from the junction of the Wurdah and Godavery rivers (the basins of which they separate), till they are lost in the gradual rise of the country to the

* A beautiful variety of chabasie, having the angles replaced by triangular or pentagonal faces supporting a rhomboidal surface, of which beautiful specimens abound in certain localities of the western portion of the formation, has not been met with in this neighbourhood; but, like some other minerals of the basaltic district, it is not generally diffused in the rocks where it is most abundant; so that I have travelled for several hundred miles without meeting with it.

west, near Lonar (lat. 20°, long. 76°, 30′), in the province of Aurungabad. Their direction is W.N.W., and, as far as can at present be inferred, they seem to be continuous to the east with numerous ranges of basaltic, sandstone, and granitic hills, extending to the Eastern Ghàts, at the lower parts of the course of the Godavery. The extreme breadth of the range, from the foot of the Nirmul pass to the town of Yedlabad, (nearly on a level with the plain country of Berar,) is about 40 miles; but several smaller hills having for the greater part the same direction, are intimately connected with them to the north, as far as the Wurdah river, which has an elevation of little more than 600 feet above the sea. The Sichel hills are arranged in terraces, with steep sides having projecting spurs, and their summits rise occasionally into conical elevations with rounded or flat tops. They inclose narrow valleys abounding in streams, or support table-lands covered with black soil strewed with trap boulders, and having water everywhere near the surface. A thick wood and grass jungle, composed of very different plants from those common on the granite hills, cover the whole tract, with the exception of the flat summits and some of the terraces, and render it unhealthy for the greater part of the year. The basalt of which they are composed, is generally globular, the spheroids being sometimes of great size; but in many of the water-courses, even of the elevated table-lands, it has a stratified appearance. Small basaltic columns are also met with on the crests of some of the spurs and higher ridges; and where they occur, no fossils and few minerals are found. Granite not only forms the base of the hills at Nirmul to the south, and Yedlabad to the north, but part of the mountains themselves, the basalt being seen to rest on decomposing granite about the centre of the range, in a deep ravine, through which the Koorm river passes; it also again appears high in the table-land to the north of that river, and in one of the terraces of the northern descent, where the most extensive fossil beds were found. Further detail is unnecessary, as Dr. Voysey's admirable description of the Gawilghur mountains, forming the northern boundary of the great and fertile valley of Berar, as these hills do its southern limits, applies equally well to both ranges*.

The fossils were first discovered *in situ*, near Munoor, in the basaltic table-land north of the Koorm river; and were subsequently found in the descent of the hills towards Hutnoor, and in different parts of the Mucklegnudy pass, leading into the Berar valley. They consist of numerous gyrogonites; two species of Cypris; two, or perhaps three, species of Unio; and many individuals referable to the genera Paludina, Physa, and Limnea. (Pl. XLVII.) The rock in which they occur, varies in different places. Some of the finest specimens were procured from a red chert with scabrous

* Asiatic Researches, vol. xviii.

surface, having silicified shells distributed throughout its substance, or projecting from its surface. The chert is deeply imbedded in the nodular basalt, from which it projects in some places several feet. The finest specimens of Unio occur in a beautiful gray chert, imbedded in the basalt, or resting immediately on it, the under surface being plain and smooth, while the upper is rough, from portions of the large shells which project from it. On breaking up one of these masses, it was found to contain entire Unios, many of them having the valves connected and closed, or partially open; the interior being filled with the same chert, spotted with fragments of shells, minute univalves, and fine specimens of the two species of Cypris, which occur so abundantly. Some parts of the rock exhibit a mixture of sand, clay, and fragments of shells, of very moderate hardness; but the greater portion consists of chert, the materials of which are occasionally arranged in a beautiful, light blue, enamel-like substance, around irregular cavities containing crystals of purple quartz. Some portions also exhibit a minute vesicular structure; and the whole appearance of this beautiful rock forcibly impresses the mind with the conviction, that it owes its present appearance to the action of the great basaltic eruption, which has enveloped it and the organic remains. The greater number of the shells are converted into chert, but a few retain their original structure; and in some instances the calcareous matter has been converted into crystals of calcareous spar. Many internal casts of entire shells are found in the substance of the rock, to which they are united at a few points only, a greater or less space being left unoccupied; in others, the entire shell is converted into siliceous matter, retaining the appearance even of the ligaments unaltered; and fortunately, in a few cases, the hinge and teeth are excellently preserved.

Numerous fragments of shelly rock, differing much in appearance, lay scattered about over the table-land; consisting partly of a fine blood-red chert, like that above described, and containing the same shells. The gray chert was more sparingly distributed, and the Unios did not occur in the other fragments. Some of them, composed of a tough white clayey stone, so soft as to soil the fingers, contained Physæ, Paludinæ, and Limneæ, mostly converted into calcedony, but others also retained their original structure, and effervesced with acids. Portions of charred vegetable matter, resembling small fragments of grasses and reeds, occurred in these and the harder cherts. Other specimens are composed of a greenish blue crystalline mass, resembling an ore of copper, (but it is of low specific gravity, and contains no trace of that metal,) and the shells contained in them are converted into the most beautiful crystalline quartz, retaining the form of every convolution of the Physæ and Paludinæ. The cells of this stone are often coated with fine silky crystals. Masses of a hard coarse chert, consist almost entirely of Gyrogonites, but contain many of the same Physæ and Paludinæ. This rock appears to have formed beds of about half a foot in thickness; but it was not discovered *in situ*. A stratified rock was however found in the neighbourhood, resembling some specimens of the argillaceous limestone of the diamond districts, but consisting of a compact whitish chert, which contained Paludinæ, and the finest specimens of Gyrogonites. (Plate XLVII., fig. 1.) Night prevented the connexions of this rock from being determined: the strata were, however, ascertained to be of considerable extent, and to be much buried in the soil; there were also numerous fragments of siliceous rock, partly converted into a black bituminous flint, or a coarse quartzose rock, partially altered into calcedony, by which most of the shells were also replaced.

The masses of red chert protruding from the basalt contained, besides the Testacea, small portions of silicified wood, and what I consider to be the fragment of a bone, and of the tooth of a mammiferous animal. The specimens, however, are too imperfect to admit of any certainty as to what they really are; but it is not unlikely that such remains should occur, and I therefore do not suppress what may lead to a more successful inquiry.

On descending towards Hutnoor, granite, presenting a concentric, ligniform surface, from the unequal decomposition of the quartz and felspar, occurs at a short distance from the fossils*. With this exception, the basalt continues of the same character as before, and fragments of red or deep black chert, containing Paludinæ, are found in the beds of torrents; and at Hutnoor they occur in the trap. There is much calcareous matter mixed with the soil, or collected in nodules, and it appears to be derived from the lime contained in the basalt, or between its laminæ. On the pioneers attached to our camp penetrating, at Elchoda, through some strata of tabular basalt to obtain water for the troops, seams of a pure white, pulverulent lime were found between the layers†. At Hutnoor fragments of a compact blue limestone, not to be distinguished from that of the diamond districts, were collected; and the rock to which they belonged, was found in the descent from the first of the three principal terraces by which the road leads to the northern base of the hills. The strata were much inclined and broken, but the forest was so thick, that I could not trace them for any distance. After descending to the second terrace, the surface rock suddenly changes to a white, horizontally-stratified limestone, almost entirely composed of large bivalve shells, the edges of which decomposing more slowly than the cement, the natives have applied to it a name signifying impressions made in clay by the feet of sheep. The thickness of the bed in one place, where it is intersected by a torrent, is 12 feet, and it rests directly on red granite. A great spur, from the upper part of the mountain, extends across the terrace, rising precipitously above the fossiliferous limestone, a few hundred yards from the spot where it rests on granite; and has buried the continuation of the stratum under an accumulation of basaltic *débris*. Where the limestone becomes concealed in the basalt, a friable, gray, cellular mass, resembling ashes, occurs, apparently imbedded in both these rocks. The fossils are composed of granular limestone, the matrix consisting of calcareous matter mixed with the ash-like substance, and small fragments of granite. Some of the shells are of great size, but they are ill preserved, and I found only one specimen with the valves united. These shells, I erroneously considered to be marine (principally from the appearance of those represented in Plate XLVII., fig. 4 to 8, and some of the large flattened specimens). Mr. Lonsdale, however, who had the kindness to examine some of them, considered their general character to be that of freshwater species. I had previously detected, in a fragment of a compact argillo-

* A similar appearance has been observed at the foot of the Nirmul pass, at the iron mines of Deemdoortee, and in Bundlecund.

† The same was observed in Bundlecund by Capt. Franklin. (Asiatic Researches, vol. xviii.)

calcareous stone found at the bottom of the little cliff where the granite is seen to underlie the fossils, a number of very perfect Melaniæ; I therefore re-examined the different specimens, and detected in them fragments of the same kind as those in the limestone; and Mr. Sowerby has since been able to extract from the latter, specimens sufficiently distinct to be identified with the *Unio Deccanensis* (Pl. XLVII., fig. 4 to 10,) found in the chert at Munnoor, and another species (*Unio? tumida*, fig. 11 and 12,) not yet discovered elsewhere. No other fossils were found in this locality.

When it is considered, that the accumulation of freshwater shells occurs on the precipitous descent of a mountain range, ascended with much difficulty by travellers, it will be evident that the aspect of the country has been entirely altered since these animals lived.

Country between the Sichel Hills and Nagpoor.

Towards the foot of the pass, the rock changes from the nodular basalt to amygdaloid; and near its junction with the granite, masses of greenstone porphyry, with large crystals of felspar, occur. The granite then reappears, protruding in rounded masses through the soil of the level country around Yedlabad. The bed of a stream near that town is strewed with fragments of blue limestone and schist, resembling those of the basins of the Pennar and Kistnah; and higher up the stream, a fine white quartzose sandstone, having a few imbedded fragments of quartz, is found *in situ*. It dips at a slight angle to the south-west*. The surrounding country is covered by a deep basaltic soil, so that the rock on which it rests could not be discovered; but the argillaceous limestone, passing, in its upper strata, into a greenish or red schist, is traversed by a stream a few miles to the north. Short ranges of trap hills, some of them at nearly right angles to the Sichel mountains, occur to the north-east; and beyond them, an extensive tract of sandstone has been traced for a great distance along the Wurdah.

At Zynad, argillaceous limestone appears on the surface for several miles, and agrees in every particular with the compact marbles of the diamond districts of the Pennar and Kistnah. The strata sometimes dip at an angle of 40 degrees, but they are in general nearly horizontal, the edges of the layers being disposed in steps on the slopes of gently-rising grounds. Rock crystal and calcareous spar are distributed in thin seams between the strata, as well as through the substance of the rock; and along the vertical partings of the strata, there are rows of circular cavities, which are generally empty, but are

* Minute undulations, resembling those formed by the ripple of running water, were observed on this sandstone, in a seam not quite parallel to the line of stratification.

sometimes filled with calcareous concretions. In a few instances, these hollows occur out of the line of fissure, and entirely penetrate the stratum, being connected below with horizontal channels of the same kind. On the surface, calc-tuff (Kunkur) is very abundant, often adhering to the strata, or investing fragments of the rock.

The same appearances are seen near the diamond mines of Chinoor on the Pennar, where the strata are much disturbed, and basaltic pebbles cover the banks. The only explanation which can be offered of the phenomena in both those distant localities is, that the extrication of gaseous fluids and water from below, had taken place in the lines of fissure, and had dissolved a portion of the limestone, which was again deposited in the great accumulation of tuff and conglomerate so remarkable in these places. That they at all indicate the "argillaceous limestone" to be of fresh-water origin, could never be imagined by any who had seen the rock in question, which, wherever it occurs in the south of India, is entirely devoid of fossils*. This supposition is confirmed by the phenomena exhibited at the hot-springs of Urjunah, which rise in the same rock, and where bubbles of carbonic acid are extricated through round holes in the mud covering the bottom of the rivulet, the water of which, being loaded with lime, a calcareous tuff is rapidly deposited.

A gentle elevation, extending three miles to the east of the village of Zynad, is composed of this limestone, and it rises very gradually towards a small conical summit, composed of coarse vesicular basalt, which has broken through and covered the limestone. A portion of this rock appears to have been displaced in a singular manner. A wall of perfectly vertical stratification, about 3 feet thick, projects nearly as much from the general surface, and consists internally of the same limestone, as that which it appears to cut at right angles, while externally it is singularly irregular and altered, being converted into a beautifully crystalline limestone, with quartz minerals.

To the north of this place, as far as the Payne-Gunga river, the country is flat, covered with basaltic soil or rock connected with insulated trap hills, and intermixed with jaspers, resembling those so common near Bangnapilly, and perhaps derived from the argillo-calcareous schists occasionally seen in the water-courses. The pebbles of the Payne-Gunga consist mostly of calcedonies of a reddish colour, and of argillaceous limestone, and they are in many places consolidated into a conglomerate by the calcareous matter with which all the waters of the district abound. In a layer of this conglomerate, projecting from the alluvial soil of which the bank is composed, numerous recent shells are imbedded. The limestone, and its incumbent schists, are seen north of the river, and they abound in springs and streams loaded with lime, which is deposited

* This assertion may, in the progress of knowledge, be found to be erroneous; but having carefully looked for fossils during extensive journeys through districts principally composed of this rock, I doubt whether such will be the case. Fossil plants have been reported to be found near Gundycottah; but these I ascertained to be mere dentritic markings on the surface of the strata.

as calcareous tuff in the water-courses. Masses of the same substance, several feet in height, project from fissures in the rock, or compose conical eminences of white "Kunkur," which are scattered over the black basaltic plains.

Proceeding a little further towards the Pindee hills, in which the principal of these streams takes its rise, sandstone appears on the south bank of a ravine; and on the opposite side, at a lower level, the "argillaceous limestone" so often mentioned, has been raised by some violent forces into irregular gothic arches, overlaid by partially broken but horizontal strata. The spaces within the arches are filled with fragments of the same rock forced from below. Hot springs, having a temperature of 87°, rise through the limestone, and globules of gas escape from round holes in the *débris* and mud covering the bottom of the ravine. On endeavouring to collect a quantity of the gas, there were found to be considerable and irregular intervals between each jet of air. A recent calcareous sandstone is formed in the bed of the stream, by the *débris* derived from the quartzose sandstone of the southern bank being agglutinated by the carbonate of lime of the springs.

A range of low hills having rounded summits, with conical elevations projecting from their sides, runs in a north-west direction, three quarters of a mile from the hot springs. The cap of these hills, where the Pindee Ghàt passes over them, consists of the argillaceous limestone, and the large slabs of which it is composed, are fissured in various directions, slightly convex upwards; and when taken in the mass, they have an anticlinal dip. On the summit, the strata are horizontal and in several places are remarkably altered, the argillaceous and siliceous ingredients having arranged themselves into a black chert, and a mixture of calcareous matter with streaks of a white or pale blue enamel resembling calcedony. The central parts of these bands are composed of minute quartz crystals; and irregular drusy cavities, coated with amethystine quartz, occur in the blackened flinty portions. There cannot be a clearer indication of the action of heat on a rock of a mixed character than this, even when seen in hand specimens. The whole of the base of the hill is composed of the usual black concentric basalt, the nuclei of which are exceedingly hard and contain much olivine; and to its intrusion the alteration of the limestone, with its separation from the strata below, is, without doubt, to be ascribed.

Many hills composed of concentric basalt are scattered over the neighbouring country, in insulated masses or long ranges rising in terraces, and having flattened summits. The sides of the hills between the terraces are steep, and their outline is well defined; the rock also is black and devoid of vegetation. The terraces occur at very different levels in different hills, rising

from the same plain; and their whole appearance indicates that their remarkable form is due to the circumstances which attended their elevation; and that they have not been subjected to any extensive denudation.

About five miles north of the hot springs of Urjunah and four miles south of those of Kair, sandstone caps a gently rising ground, covered with basaltic soil. Near the last-mentioned town, many hot springs rise in the argillaceous limestone, which has been remarkably broken up and altered by the globular basalt protruding through it in different places, in masses several of which are only a few yards in circumference. The limestone is, for the most part, nearly horizonal, but it is occasionally more or less inclined, and, as is usual with this formation, it has no regular direction or line of bearing. In a deep well near the village, the water of which is of the usual temperature, the limestone is unaltered; but above the principal hot spring, some of the most remarkable effects of igneous action in changing a stratified rock, are exhibited. The principal part of the small hill is a whitish limestone, the stratification of which is obliterated, and the rock projects in irregular masses full of cavities passing deep into the mass of limestone, which is partly crystalline, and in many places mixed or coated with jasper and quartz crystals. Much calcareous tuff ("Kunkur") is associated with these altered rocks, and it fills up many of the cavities; it is also found in the divisions of the nodular basalt, and masses of it, scattered over the surrounding country, are the only remains of springs which have been long closed up. Some portions of the rock had the appearance, on the surface, of a semifused brick, and had assumed something of a regular arrangement, while the centre was composed of the limestone little altered. Large masses of porous scoria also lay about.

The principal springs issue at the foot of the rising ground, where the rock is most remarkably altered. Their temperature (87°) was the same as that of Urjunah, on the other side of the Pindee hills, and it did not vary during the hot and cold months of 1831 and 1833. The water of this and many other springs is said to be equally copious at all seasons, covering the neighbouring country with the richest vegetation, when all beyond is a black and parched waste. On issuing from the rock, the water is sensibly acid, and in one spring, carbonic gas escapes with the water. It is remarkably agreeable to the taste, and sparkles in the glass, as well as where the stream passes over rapids. It contains a little muriate of soda, a minute quantity of sulphates, and much carbonate of lime in solution, which is deposited on boiling, and in the bed of the rivulet, where it has formed considerable masses of rock chiefly composed of the petrified vegetation of the banks. So quickly is this deposit formed near some little falls, that shells appear to be imprisoned and entombed while adhering to the face of the rock; and tufts of grass are encrusted with sediment while their roots are still alive. If any doubt remained as to the nature of the nodular limestone, known in India by the name of "Kunkur," it would be removed by the sight here exhibited of all gradations of this substance actually forming, and varying from

pulverulent lime to a crystalline rock. The water is probably derived from a great depth, the springs having, as already stated, the same temperature as those of Urjunah, and not being materially diminished by the failure of the annual rains.

Sandstone forms the surface rock in different directions over the surrounding country, but I had an opportunity of examining it carefully only at Won, eight miles north of Kair, its junction with the limestone being concealed by basaltic soil, mixed with calcedonies, fragments of that rock, schist, and of a coarse puddingstone, which I did not find *in situ*. The hill of Won is composed of sandstone, dipping in all directions from the apex, and varying in colour from white to red and yellow. It contains also ferruginous grains or scales, either in seams or disseminated through its substance. In a fragment of this kind much resembling the cement of the Bangnapilly diamond breccia, a fossil was discovered having a compact structure and deep black colour, and it is probably a portion of a hollow, compressed vegetable, the centre of which is filled with the sandstone. It is the only instance that has come to my knowledge of a fossil being found in the sandstone of southern India; and as the rock corresponds in geological position and mineralogical characters with the diamond sandstone, the fact is of considerable interest, even if the formations were not found to be continuous, as will be stated hereafter. The specimen is deposited in the Museum of the Asiatic Society of Bengal.

Sandstone, argillaceous limestone, and schist constitute the building-stones of the surrounding country, which is much buried under basalt, and a black alluvial soil containing calcedonies, jaspers, &c. A few miles south of Chicknee*, (where the fossils were again met with,) the red schist found above the limestone south of the Urjunah hot-springs and in various places of the diamond districts of the south, reappears, intermixed with protruding masses of basalt, which have altered it in the most singular manner,—the lime of which it is in part composed, being converted into a fine crystalline mineral, in which the red clay is enveloped or diffused, giving the rock and even hand specimens a very striking appearance. Near Chicknee, the schist rises slightly towards a basaltic ridge, in which the fossiliferous chert is likewise imbedded. The schist is divided into minute rhombs by vertical partings, in which veins of calcareous spar from an eighth to half an inch thick have been formed, and give it a beautiful, reticulated appearance. Lime is found in the schist, and portions of the red clay are enveloped in the crystalline limestone, which contains no magnesia.

The fossils occur on the surface, or are imbedded in nodular basalt over several miles, being

* Fossils were first found at Chicknee by Mr. W. Geddes, May, 1829.

found in blocks of indurated clay, chert, and flinty slate. The appearance of the indurated clay is the same as in some of the specimens from the Sichel Hills, but the clay is harder, full of cavities, and in some cases passes into perfect chert, or has waved lines of quartz or opalized matter diffused through the substance of the mass. Many Physæ, Paludinæ, and a few Limneæ of the same species as those already noticed, are found in this indurated clay or imperfect chert. Some of them are entirely converted into calcedony; others have the lime replaced by quartz, which is finely crystallized and covers the surface of the convolutions; or the columella only is preserved, passing across an empty cast of the shell. In some cases, however, the structure of the fossil is unaltered, and it effervesces in acids. Flinty slate without organic remains occurs in the neighbourhood of those amorphous masses, and many fragments of the same kind containing large compressed bivalves are scattered about. In one block of this kind, portions of palm wood mineralized by black flint, intersected by fine veins of a light blue opal, (of the same kind as occurs in some of the specimens of fossil wood from Antigua, lately presented to the Society by Mr. Stokes,) was found associated with compressed very thick bivalve shells, probably referable to the same species as those of Munnoor.

Every appearance presented by these rocks indicates the action of the semi-fluid basalt on the beds of mud and sand, probably derived from the neighbouring sandstones and schists, in which the shells previously existed.

At Hingan-ghàt*, a few miles further to the north, considerable fragments of silicified palms and other plants were found in a black chert lying on the basalt, and similar masses, but without fossils, were imbedded in it. I met with no organic remains to the north of this town, the whole country as far as the city of Nagpoor being covered with a rich black soil, from which insulated basaltic hills with flattened summits rise abruptly.

Of these hills the most remarkable is that of Seetabuldee, which is based on decomposing gneiss and mica slate. To Dr. Voysey's description† I have nothing to add; but as it has been inferred‡, that the "flattened summits and long flat outline" of the low ranges connected with this celebrated hill, and forming the eastern part of the great trap district, are composed of basalt

* In examining with the microscope sections of some of the silicified wood from the district described, a specimen from the chert of Hingan-ghàt appeared to me to be bone, and Mr. Owen, who has had the kindness to examine it, has ascertained it to belong to a mammiferous animal. He has favoured me with the following note on this important fossil:

"A section of this fossil was prepared sufficiently thin to allow of its being examined by transmitted light under a high magnifying power, when it was found to possess the structure characteristic of bone. Sections of 'Haversian canals,' with their concentric lines, were everywhere present, interspersed with numerous Purkingian cells or corpuscles: the size and disposition of these characteristic parts of the osseous structure agreed with those of the bones of the Mammalia. It was highly satisfactory to find the microscopic test as available in demonstrating the presence of bone, when ordinary characters and the unassisted eye would have left the matter doubtful, as it is in reference to the determination of the teeth."—July, 1839.

† Asiatic Researches, vol. xviii. ‡ Geological Transactions, Second Series, vol. 4th, p. 410.

having the same stratified appearance as that of other parts of the formation, it is necessary to mention, that they are formed of globular basalt such as has been already described, or of basaltic columns of very regular forms, which diverge from the centre of the hill and incline outwards at an angle of 45° with the horizon, or form a figured pavement on the flat summits.

Origin of Minerals in Trap Rocks.

The lower part of the hill of Seetabuldee itself exhibits a tendency to columnar structure, caused by horizontal and vertical partings, the sides of which are coated with thin plates of calcedony, and, according to Capt. Jenkins*, of calc spar. These minerals are not confounded with the substance of the basalt, and may be the result of infiltration or sublimation of siliceous and calcareous matters. In no other situation did I meet with an example in which either of these processes would account for the occurrence of the calcedonies, zeolites, calc-spar, &c. found in the amygdaloids and nodular basalt of India. Almost everywhere, calcareous spar is more rare than siliceous minerals, which would not be the case were they derived from infiltration, if we are to interpret the past by the present operations of nature. Wherever I have met with the basalt, and in the neighbourhood of every greenstone dike or insulated mass of that rock, and under every layer of basaltic soil in India, calcareous matter is deposited, and has even occasionally a crystalline structure. In the escarpments of the Mysore ghàts, veins of basalt, not two inches thick, ramify through the granite, and are coated with a compact layer of carbonate of lime. Voysey found the granite in the neighbourhood of the basalt intermixed with calcareous matter, indications of which I have myself seen, in the deposit of tuff on the summit of granitic logging-stones near greenstone. If, then, we suppose infiltration to have deposited the calcedonies, agates, &c., &c., when chemical action is presumed to have been more powerful than at present, a greater number of the cavities would have been filled with lime than with such intractable substances, which is not the case. These are also frequently intermixed with the basalt in a manner which could have been produced only by their being formed simultaneously. I have seen masses of calcedony, passing into a black mineral not to be distinguished from the surrounding basalt. They also occur in the compact nodules where no fluid could have had access, and even in the cavities of the Seetabuldee basalt, lined by an impervious glassy coat. In this rock, likewise, calc spar occurs, penetrated by needle-like crystals of the same substance, invested with a crust of the basalt and connected with each side of the cavity, and resembling chiastolite in structure. It is indeed impossible to conceive how many of the appearances presented by the agates, cornelians, or drusy cavities in calcedony, partially or entirely filled by quartz crystals, or a central mass of calc spar, could be formed in the way supposed, as the first coating of silex would effectually close out the further access of the aqueous solution of that substance ; nor could layers so formed, separate into distinct cavities, having both sides covered with quartz crystals, as they are sometimes seen to do. It is, however, only by a careful study of the rocks themselves, that this can be fully understood. I have selected a few specimens to show that the majority, if not all the minerals of the Indian trap rocks, are not formed by infiltration. One of these, perhaps, deserves particular notice; it is a mass of calcedony, 8 or 10 inches in length and 6 or 8 in diameter, of a conical shape, and was found imbedded with its apex downwards between the globular basalt, and impressed with the irregularities of its surface. In another of these specimens the upper part is perfectly flat and

* Asiatic Researches, vol. xviii., p. 199.

smooth, without any impressions of the basalt, and is composed of a thick covering of cachelong, parallel stripes of which appear to indicate the slow cooling of the surface. The centre of the mass is composed of quartz crystals, radiating to the centre, which is occupied by calcareous spar impressing or impressed by the quartz. The mode of its occurrence increases the conviction in my mind, that the only correct theory of the formation of such minerals in trap rocks, is the play of the molecular attractions existing between similar particles of matter. That so eminent an inquirer as Dr. Turner should have asserted that all calcedonies, rock crystals, &c., even when occurring in volcanic rocks, are the result of aqueous infiltration *, I can only account for, by the difficulty of explaining how carbonic acid is retained at high temperatures, in any other way than by supposing a great pressure to have existed at the time the rock was in an ignited state; but of the existence of which, proof is often entirely wanting where crystals of carbonate of lime occur. The phenomena exhibited by the vesicular trap, scoriæ, and porous chert associated with the Indian basaltic and fossiliferous rocks, satisfied me, that at the time of their formation they were subject to no pressure sufficient to retain the carbonic acid of the altered limestones, and of the shells and calc spar inclosed in the geodes; but no other explanation presented itself, till I was informed by Mr. Faraday of his beautiful experiment of exposing carbonate of lime in perfectly dry air to the heat of the oxy-hydrogen blowpipe, without driving off its carbonic acid. In the simple apparatus employed by him to show that the retention of the acid depended on the absence of moisture, no pressure of any consequence could be exerted on the lime. Guy Lussac has lately published some experiments on the effect of aqueous vapour in assisting the escape of carbonic acid from limestone, and concludes, that its agency is trifling †; but as he does not appear to have taken the precaution of drying the atmospheric air by passing it through sulphuric acid, as was done by Mr. Faraday, they cannot be considered as invalidating the beautiful results obtained by the latter. His observation, however, that the water contained in limestones is driven off before the carbonic acid and at a much lower heat, is important, in showing that the calcareous matter in a rock exposed to volcanic action may lose its water before the carbonic acid, and be thus reduced to the state of the carbonate of lime in Mr. Faraday's platinum tube. These facts will assist in explaining the anomalies observed in the fossils of the district above referred to, which often retain their carbonic acid when portions of the rock in which they occur have been fused by the inclosing basalt, while other portions are vesicular from the escape of gaseous matters. The whole phenomena, indeed, would admit of explanation by supposing, what must in fact have occurred, the presence or absence of moisture during the various degrees of heat to which the rocks were exposed in the progress of the eruption, and in the course of cooling. A shell, in one part of a rock, may thus retain its carbonic acid, while in another portion it may be reduced to quick lime, subsequently carried off by the water, leaving only a cast; and a third may be replaced by silica, or the form of its convolutions taken by fine quartz crystals, perhaps derived from silica rendered gelatinous by the lime with which it was ignited ‡.

In stating these views, I venture only to express an opinion forced on me by the phenomena under description, and which appear to explain some of them better than the theory of pressure, which, however useful in removing the prejudices against the igneous origin of the trap rocks,

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* Lecture on the Chemistry of Geology, by Dr. E. Turner, Edin. New Phil. Journal, Oct., 1833.

† Annales de Chimie et de Physique, Oct., 1836.

‡ For a knowledge of the fact, that lime calcined with finely-divided silica, acts like the fixed alkalis in rendering it gelatinous and soluble in weak acids, I am indebted to Capt. Smith of the Madras Engineers, F.R.S.

has been injurious in leading geologists to admit too easily the existence of aqueous pressure, or extensive denudations of solid rocks, supposed to have confined the carbonic acid at the time of eruption. No doubt pressure is an efficient agent in some cases*, but not in many to which it has been applied.

The trap terminates in the line of section, a few miles to the north of the city of Nagpoor, and is succeeded by a red sandstone, the strata of which are bent, fractured, and converted into a compact quartz rock, at the point of contact with the granite which has burst through it. Within a few hundred yards of the ravine where these phenomena were observed, mica slate occurs, and a little beyond, some hills of gneiss. A bed of granular limestone is quarried at the foot of a conical hill of basalt, in part composed of a scabrous quartzose, and calcareous rock, abounding in drusy cavities, calcedonies and cornelians. Further north, granite veins pass through a much-elevated limestone, varying in colour from red to gray and black, and the stratification of which is nearly obliterated. The gneiss and mica slate forming the neighbouring hills are also penetrated by dykes and masses of granite†. To the north of this district are 50 miles of a wild mountain country, composed of granitic rocks, with trap in the ascents and tops of the passes ; the basalt then reappears, and composes great part of the valley of the Nerbudda.

In a direction south-west of Nagpoor, the nodular basalt is the only formation met with as far as Baitool (90 miles), where granitic rocks reappear, but are succeeded by fine-grained sandstones with traces of coal, and penetrated by trap dykes ranging from S.E. to N.W‡. Here, the sandstone rises into mountains, and constitutes what appears to be the continuation of the range forming the division between the valleys of the Taptee and Nerbudda rivers ; and "indurated clay," containing casts of the same shells as those of the Sichel range, also occurs.

Before proceeding to notice more particularly the fossils, and the evidence they afford of the geological era of the intrusion of the basalt, it is necessary to make some observations on the Sichel range, and the connexions of the several formations occurring in the district described. The basaltic rocks of Nagpoor and of the country to the south, have been considered by every observer to form the eastern part of the great basaltic formation of Western India, with which it is continuous, and with which it agrees in every particular of general character and mineralogical structure, and in being connected with stratified rocks, which, as far as is yet known, are of the same age. The only difference is, that towards the eastern limits of the formation, the hills are

* Transactions of the Royal Society of Edinburgh, vol. vi., p. 120.

† Captain Jenkins, in Asiatic Researches, vol. xviii.

‡ Lieuts. Miles and Finnes, Journal of the Asiatic Society of Bengal, Feb., 1834, and Dr. Spilsbury, August, 1834.

less elevated and the trap breaks through the granite and stratified rocks, while to the west the mountains are, with a few exceptions, entirely composed of basalt from the level of the sea to the loftiest summits.

Lonar Lake, &c.—The Sichel hills, which have heretofore attracted little attention in a geological point of view, terminate to the west in the neighbourhood of Lonar, near what appears to have been a vast crater in the centre of the great basaltic district. As it is the only instance of a volcanic outburst discovered in this immense Plutonic region, a more detailed account of it than has yet been given to the public, may not be unacceptable*.

It is a nearly circular or oval depression, in a country composed of tabular and nodular basalt, and sloping gently towards it on every side. It is between three and four miles in circumference at the upper margin of the precipitous escarpment which rises from the bottom of the valley about 500 feet. The extent from which the water is collected may be about six miles in circumference, but no measurements were made. Two small streams fall into it from above; one issuing from a pagoda, to which it is carried from the gentle slope behind; and the other passes over a small cliff,

on which it deposits a considerable quantity of stalactite. The sides of the crater are covered with a forest inhabited by tigers and game; and the bottom is occupied by underwood, a few fields, in the irrigation of which the water of the streams is nearly expended, and by a small lake of salt and bitter, greenish water, surrounded by a muddy shore, and varying in size at different seasons. Many sweet springs issue from the saline mud, and a well is built within its highest level, the water of which stands at the same height as that of the lake, though issuing from a depth of nearly twenty-four feet.

I have carefully examined the water of this well, and that of the small stream at the pagoda above. This last had a specific gravity of 1000·6; and 2000 grains, evaporated at 212°, gave a solid residue of $\frac{7}{10}$ of a grain, the greater part of which consisted of muriate of soda with a little sulphate, and the remainder of carbonate of lime. The water of the well below had nearly the same specific gravity, but contained in 2000 grains, one grain of solid matter, of which $\frac{7}{10}$ of a grain were soluble in water, and contained muriate of soda and a little sulphuric acid and lime; the insoluble part consisted of carbonate of lime. Neither of the waters contained any trace of alkaline carbonates or of magnesia. It is unnecessary to go further into the analysis here, as another bottle of the same water had a higher specific gravity, and contained more lime, a circumstance sufficiently accounted for by the escape of a portion of the carbonic acid from the other specimen. The water of the lake is clear, and has no unpleasant smell; but the mud at its bottom is strongly impregnated with sulphuretted hydrogen. In February, 1834, when the specimens were collected, the lake was in no place more than 5 feet in depth of water and mud, but when full it may be eight or ten feet deep in some parts. A layer of salt 2 or 3 inches thick covered the bottom *under the mud*, and when broken up and removed, was found to be composed of a middle plate, with radiating laminæ above, and having a striated appearance below. That obtained by diving and bring-

* Captain Alexander has published a notice of this lake in the Transactions of the Literary Society of Madras, and in the Edinburgh Philosophical Journal; but he must have examined it very cursorily or he would not have overlooked its real nature, and stated it to be unfathomable, when, in fact, the water is everywhere shallow. An extract from a private letter to Mr. Prinsep, and published in his Journal for June 1834, was written before I had myself examined the chemical history of the lake.

ing up baskets of the black mud, at a season when there was much more water in the lake*, was also formed under the surface of the mud in lamellar spiculi radiating in every direction†. The salt accumulates slowly, and is collected only once in several years, the quantity having diminished in consequence of the mounds erected above the edge of the crater to regulate the supply of water, having been neglected; but it is evident, from the great beauty of the specimens obtained, that the quality is not affected by this cause. The salt is collected at the end of the dry season, when the water is low; and I observed mounds of the black mud on the banks, covered with an efflorescence of tabular crystals. The salt is used for washing and dying chintzes, &c., and is exported to considerable distances. I imagined that the water of the lake in which such large quantities of salt were deposited, was saturated; but I found its specific gravity to be only 1027·65, a solution of the salt itself obtained from the bottom at the same time being 1148·4; and the water rapidly dissolved the crystals thrown into it. On analysis, the salt was found to consist in 100 parts: of carbonic acid, 38; soda, 40·9; water, 20·6; insoluble matter, ·5, and a trace of a sulphate. This nearly corresponds to the composition of the trona or striated soda from the lakes of Fezzan, examined by Mr. R. Phillips‡; but approaches somewhat nearer to the equivalent numbers of the sesquicarbonate established by that analysis, which is to be ascribed to the greater purity of the Lonar salt. The water of the lake contained besides, a little potash, muriate of soda 29 grains, sesquicarbonate of soda 4·2 nearly, and sulphate of soda ·1 of a grain in 1000 grains of the water. No lime could be detected in it, nor did I discover any magnesia. These facts confirm Berthollet's theory of the formation of carbonate of soda in the natron lakes of Egypt, viz. that of a mutual decomposition of the muriate of soda and carbonate of lime when in a pasty state.

The striated soda of Fezzan and of this lake, containing half an equivalent more of carbonic acid than can be furnished by carbonate of lime, renders some modification of his theory necessary; and the most probable explanation appears to be, that the carbonic acid by which the lime is held in solution in the mud, furnishes the acid, and perhaps indicates the existence of an unstable sesquicarbonate of that substance; which is not improbable from other facts in the history of the union with that acid. This was suggested by my friend Captain Smith of the Madras Engineers, and explains the circumstance sufficiently.

Like most points in physical science, these observations have other and more extensive applications than that of affording an explanation of the production of natron in this lake. Carbonate of soda is extensively distributed over the surface of the soil in various countries, more especially in the basaltic portion of Central and Western India, and in the limestone districts of the south; the real relations of which have been a subject of discussion amongst Indian geologists, and inferences unsupported by fact have been drawn from it. In all the places where I have met with it, or of which detailed information has been obtained, muriate of soda and carbonate of lime existed in the soil, and the natron was found on the surface of the moist earth or mud. Near Gundycottah on the banks of the Pennar, common salt is interstratified with the upper schistose strata of the argillaceous limestone on which the sandstone rests; and on the surface of the neighbouring soil, natron, contaminated with much muriate of soda, is collected and used in washing and in glass-making. The salt associated with the limestone, and the water of a saline well dug through it, having the specific gravity of 1002·5, contain common salt and a little sulphate without any carbonate of soda, which is no doubt produced in the same manner as the Lonar salt. I did not ascertain whether it was also a sesquicarbonate, but I have examined a portion of native carbonate of soda from another part of India, with which Mr. Faraday had the kindness to furnish me, and I found it to be composed of a mixture of that salt with muriate of soda and a little sulphate. The same is probably true of the carbonates found in other countries in similar situations§. A

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* July, 1824.

† The natron of a lake near Maracaybo in South America occurs in the same way, the Indians breaking up the layers of salt with long poles; and then, by diving, they remove it from under a bed of mud which covers it, and they place it in small canoes, as is done at Lonar. Journal of the Royal Institution, vol. i., p. 188.

‡ Journal of the Royal Institution, vol. vii., p. 294.

§ The carbonate of soda formed by the incineration of saline plants in the deserts of Northern India, and by the deflagration of nitrate of soda and charcoal in the south of the Peninsula, must not be confounded with the natron found in the soil.

specimen, however, procured from the water of a deep well near London, passing through the London clay into the chalk, which I received from Professor Daniell, contained the carbonate; but as the sesquicarbonate is decomposed by a low heat, no inference can be founded on the examination of specimens obtained, as this was, from the boiler of an engine.

The absence of Lime in the water of the Lonar Lake is a remarkable circumstance, but easily accounted for, as the sesquicarbonate of soda and the water itself precipitate the sulphate and muriate of lime, notwithstanding the mutual decomposition they undergo when in a semifluid state. The Lake of Ourmia, in Persia, is stated by Dr. Marcet to contain no lime, although of a specific gravity of 1165·07, and abounding in sulphates and muriates. This appeared very remarkable in an inland sea nearly 300 miles in circumference, situated in a volcanic country. On referring to the works of travellers*, it appeared that the streams flowing into it abounded in lime, which is deposited in large quantity in the form of a beautiful travertine. The lake is shallow, and at certain seasons much of it is nearly dry; the water is clear and transparent, but the mud of the bottom is loaded with sulphuretted hydrogen, and thick layers of salt, formed in it under the water, are redissolved on any agitation. No fish can live in it. All these phenomena are exact counterparts of those exhibited at Lonar, but no information is given as to the salt collected from its saline mud, except that Sir John Malcolm states, the salts are bitter and different from those of the sea. I am, therefore, strongly impressed with the conviction, that sesquicarbonate of soda is formed from its waters as at Lonar, and precipitates the lime. Dr. Marcet, however, has given, in the Philosophical Transactions for 1819, the results of an examination of a small quantity of this water, which he states to be as follows:

1. Precipitate from 500 grains of the water by nitrate of silver ..... 237·0
2. By nitrate of baryta ..... 66·0
3. Magnesian precipitate by carbonate of ammonia and phosphate of soda ..... 10·5

and he infers, that although it contains no lime, it yields twenty times as much sulphuric acid and six times as much muriatic acid as sea water does. But Dr. Marcet had only 150 grains of this water to operate on, and merely gives in a tabular form, along with many specimens of sea water, the quantity of precipitate caused by the various reagents; and there is no evidence that the precipitate from muriate of baryta was not, in part, caused by carbonate of soda. It is, at all events, worthy of the inquiry of future travellers†.

The Lake of Ourmia, like that of Lonar, contains potash, which I did not not detect in the springs running into the latter, but its source is no doubt in the decaying (and when I visited it, burning) trees on the surrounding precipices. The sulphuretted hydrogen adhering to the clay has been supposed to be derived from volcanic sources, but I have observed the same phenomenon in the salt water inlets along the Indian coast, wherever the bottom contained argillaceous and carbonaceous matter; and it even goes so far as to form considerable quantities of sulphur and, I have reason to believe, sulphuric acid, although on this point the proof is defective. The effect is to be ascribed to the decomposition of the sulphates of the water by the carbon; and the clay probably only prevents its passing off into the air or mixing with the water, by the power of adhesion. Similar actions have gone on in former times in the alluvium on which the city of Madras stands, and probably in more ancient deposits‡.

The ancient crater of Lonar seems never to have been an active eruptive vent, as no scoriæ or lava currents can be traced around its margin, which is too distinct and unaltered to admit of any probability of these having been subsequently removed by denudation. A certain degree of for-

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* Sir John Malcolm's History of Persia; Sir Ker Porter's Travels; Ouseley's Travels; Journal of the Geographical Society, vol. iii. &c.

† If a carbonate exists in the water, it must be of the same composition as that of Fezzan, Maracaybo, and Lonar, as the carbonate would precipitate the magnesian salt, which the sesquicarbonate would not.

‡ No sulphuretted hydrogen can be detected in the water of the springs running into the lake. The hot spring of Anhoni Simhoni, in the sandstone and basaltic district between the valley of Berar and the Nerbudda, I have found to contain sulphuretted hydrogen and muriate of soda, without lime.

cible elevation was sustained by the margin of the lake, when the explosion or subsidence happened from which the great depression took its origin.

From Lonar the basaltic district extends to the south as far as Beder; to the west, 200 miles to Bombay; and northward, to the banks of the Nerbudda, near the ancient cities of Indoor and Mhysir, reported to have been buried at a remote period under volcanic eruptions. To the east, the great basaltic country of Berar extends as far as Nagpoor; and the Sichel range passes in a S.E. by E. direction to the confluence of the Wurdah and Godavery, and towards the eastern ghàts. Hot springs and streams loaded with carbonate of lime, occur along the line of elevation of these mountains at Mahoor, Urjunah, Kair, Byorah, and at Badrachellum, a short distance above the pass through which the Godavery reaches the alluvial plains of the coast. The spring of Byorah is surrounded by sandstone and limestone rocks, and carbonic acid escapes with the water, which has a temperature of 110° and holds lime in solution*. That of Badrachellum, which rises in the sandy bed of the Godavery, has a temperature of 140°, and contains sulphuretted hydrogen, also sulphates and muriates of soda and lime. A sandstone resembling the cement of the Bangnapilly diamond breccia and the rock of Won, protrudes from the sandy bed of the river near the spring; and granite, basalt, and a red schist resembling that so common in the diamond districts, occur in the neighbourhood; diamonds also are occasionally found. Other hot springs are reported to exist in this line of elevation; but that wild and little-known country, far removed from the residence of any European, must long remain in a great measure unexplored.

The facts stated in the preceding pages prove that the basaltic rocks, by which so much of Western and Central India are covered, are more recent than the sandstone and argillaceous limestone of the basins of the Pennar, Kistnah, Godavery, and of the mountains south of the Nerbudda; and that, notwithstanding the frequent occurrence of these rocks in a horizontal position, they have been subjected to violent operations, which have in many instances elevated the strata and remarkably altered the rocks themselves. It also appears, from observations made on the borders of the trap districts, and in other places where the primary rocks and the sandstones and limestones are not entirely concealed, that the basalt has burst forth from numerous fractures in these formations, probably simultaneously, although often forming insulated masses. It is possible, that more than one period of eruptive violence may have occurred between the era of the formation of the greenstone dykes, so common in the granitic districts, and the conclusion of the eruptions by which the fossils were entombed; but at present there is no proof of such having been the case; and all observers have considered the eruptions to have been contemporaneous; an opinion, to a certain extent, confirmed by the occurrence of the same fossils in very distant localities.

* Journal of the Asiatic Society of Bengal, vol. ii., p. 397.

The sandstone and argillaceous limestone I have myself traced, from the neighbourhood of Nagpoor nearly to the junction of the Wurdah with the Godavery, bearing the same characters as in the vicinity of the fossil beds; and I have collected specimens of the same rocks at various places between this and Badrachellum and the diamond mines in the neighbourhood of the Kistnah. This tract, for 250 miles, is nearly an uninterrupted forest, and presents many difficulties in the investigation of its geological structure. Trap rocks and basaltic soil occur in many parts of the course of the Godavery, and granite of the usual character is occasionally met with. Dr. Voysey, who investigated great part of it with his usual accuracy, describes the sandstone as constituting a range of mountains 60 miles in extent, to the north-west of Badrachellum; and the surface rock 20 miles south of Ellore (near the alluvial plains of the Kistnah and the diamond mines), also at Mungapett on the Godavery, where I found silicified wood resembling that of Pondicherry*. Fossil wood was also seen by Mr. Geddes strewed over the country N.W. of this point, towards the junction with the Wurdah. Where the sandstone of the Godavery meets the granite to the west, Dr. Voysey states that it can hardly be recognised as the same rock, consisting of a conglomerate containing quartz, felspar, and rounded pieces of granite resembling that of the eastern ghàts. The argillaceous limestone occurs in the same district, and is more widely distributed than Dr. Voysey supposed. He found it at an elevation of 2600 feet above the sea, and exhibiting marks of great disturbance, dipping to the S.E., and at the summits of the hills intermixed with quartz rock†. Dr. Voysey considers these formations at the lower part of the Godavery, to be the same as those of the Kistnah and Pennar; and in this opinion I fully coincide, although I have found the continuity of the sandstone and argillaceous limestone to be interrupted by a narrow band of granite, extending from the delta of the Kistnah to the granitic platform of the Deckan. Some of the hills, however, have caps of sandstone. In the present state of our knowledge, it is difficult to form any correct notion as to the dip and direction of these rocks. Indications of derangement and elevation by the granite are, however, sufficiently apparent.

Sandstones and schists of the same characters, and associated with the same rocks, are also extensively distributed along the great tributaries of the Kistnah, in the southern Mahratta country, near the western ghàts, and a little to

* Journal of the Asiatic Society, vol. ii., p. 402. The tenor of Dr. Voysey's observations in this place seem to show that he considered the "clay slate," in which he included the sandstone, to belong to the same formation as the limestone; a conclusion I had formed before meeting with his paper, and which has not been expressly stated in any of his writings yet given to the public.

† The structure of the wood is beautifully preserved: it is coniferous. June 24, 1839.

the south of the part of the basaltic district described by Colonel Sykes (Geol. Trans., 2nd Series, Vol. IV.). The limits of this part of the formations have been but imperfectly traced. According to Dr. Christie's observations and my own, they are the same as those of the Cuddapah district*. The occurrence of sandstones and stratified limestones in this situation, is a fact of great importance, which has escaped the notice of those, who have speculated on the period of elevation of the great mountain chains of the peninsula. It was for this reason, that I selected the line of section from Madras to Atchera, on the western coast, within the limits assigned by Colonel Sykes to the basalt, and near to which I discovered the sandstone *below* the escarpment of the western ghàts. (Section 2, Plate XLVI.) In the pagoda of the town, I observed several quartzose sandstone pillars; and I discovered the rock itself forming a small range of hills to the south of the town, and dipping at a considerable angle to the N.W. The stone is similar to that of the hills, near the Chinoor diamond mines. The rock at the entrance of the inlet is laterite, having the appearance of horizontal stratification; and there are some indications of trap below it; but of this I could not obtain positive evidence. Colonel Sykes, however, states that the basalt occurs a little to the south at Malwan; and I found it at Colter, and other places to the north, underlying the laterite, at the foot and on the escarpments of the hills. These facts are sufficient to show, that the elevation of the western ghàts in this part of their course, was posterior to the deposition of the sandstones, which, for the present, must be considered as contemporaneous over all the districts described. I am aware of the uncertain nature of mineralogical characters, as characterizing different formations; but in rocks exhibiting such remarkable appearances and relations over such extensive areas, and when no organic remains exist in them, I do not think it wrong, to place some confidence in the evidence they afford, more particularly in the south of India, where the rapid changes of formations, so common in Europe, are quite unknown.

The speculations of Elie de Beaumont on the age of these mountains is founded on negative evidence and analogies which appear to me to have little weight; nor can I consider the remarks of Dr. Benza, founded on his excellent researches on the geology of the Neilgherry mountains, as more conclusive. The non-occurrence of stratified rocks and of organic remains in a high granitic table land, affords no proof that these mountains have not been recently elevated; and the plentiful occurrence of ferruginous sandstone, containing brown coal, lignite, and mineral copal, at the foot of the Travan-

* Edinburgh New Philosophical Journal, 1828 and 1829.

core mountains, show that these inferences have been too hastily drawn, when such gigantic generalizations were to be established.

Age of the Diamond Sandstone and Argillaceous Limestone.

With regard to the age of the diamond sandstone and argillaceous limestones, my own conviction is, that they belong to the more ancient secondary, or even transition rocks; an opinion, which is not at all contradicted by their frequent occurrence in horizontal strata, as they could not have been deposited in the situations in which they are now found. The facts I have stated, will enable others to estimate the correctness of an impression founded on the structure, geological relations, and occasional nearly vertical position of the strata. On this subject, I would express no decided opinion, but recommend an examination of the junction of these formations with the stratified and unstratified primary rocks, with a view to this question.

The sandstones and limestones of Bundlecund and Malwa correspond in many particulars with those of the south of India, and have been considered by all writers as belonging to the same formations. The sandstone, Major Franklin considers to be the same as the saliferous sandstone of England*; to which it has been objected, that the salt diffused through the soil of Bundlecund may not be derived from this source, as it has never been discovered in that rock. I have also ascertained that salt occurs in all the formations of India, from granite to recent alluvium. I have, indeed, never met with a saline spring in the sandstone, but this I consider to be accidental, that rock being generally placed in inaccessible situations. I have, however, found thin seams of salt, interstratified with the upper schistose layers of the argillaceous limestone, in the immediate neighbourhood of a cliff of sandstone 300 feet in height, between the lower beds of which a similar schist was interposed. A more important objection to Major Franklin's opinion of the diamond sandstones belonging to the new red sandstone is, that in the peninsula, this sandstone, throughout 800 miles of latitude, and half as much of longitude, is *superior* to the limestone he has called "Lias." Nor can I find sufficient proof in his memoirs, or in other papers on the country between the Nerbudda and the Ganges, that this limestone reposes directly on the sandstone; and it is evident, that no inference can be founded on its occurrence at a higher level in a country so much altered by denudation and the intrusion of eruptive rocks. But should it be hereafter found, that the limestone in certain parts of Bundlecund does actually occupy a higher geological position, the fact would not be conclusive against the diamond sandstones of the north and south, belonging

* Geol. Trans., 2nd Series, Vol. iii., Part I.

(as every thing indicates) to the same formation. I am indeed of opinion, that the argillaceous limestone and the sandstone constitute only one formation, although I do not think that they should be spoken of as such in the present state of our knowledge. The basalt which has broken up and penetrated these rocks to the north and south of the Nerbudda, is connected with the same system of trap rocks, and was probably erupted at a period much more recent than either of those to which the sandstones and limestones have been referred.

Inferences respecting the Freshwater Fossils.

On the evidence on this subject afforded by the fossils imbedded in or covered by the basalt, I shall now make a few observations. For the descriptions of the shells, I am indebted to Mr. J. De Carle Sowerby*.

These fossils all belong to freshwater genera, and to species which have not yet been discovered recent. I have not been able to obtain the seeds of Asiatic *Charæ*, nor the valves of any *Cypris* inhabiting the fresh waters of India. The shells, however, all differ from those inhabiting the rivers of the neighbouring country, as far as Mr. Sowerby and myself could judge, by comparing them with a collection of recent shells, which I made during a residence of several years at Nagpoor; nor do I think it possible that any of the larger shells could have escaped my notice, did they still inhabit the northern branches of the Godavery. Colonel Sykes, also, had the kindness to allow me to examine a collection of recent shells made by him near the western ghàts, consisting of the same species as those of the Berar valley, and they are of course different from the fossils. I also failed to detect amongst them any of the shells contained in a large collection of recent land and freshwater Testacea from Bengal, presented to the Zoological Society by Mr. Benson. It may therefore be inferred, that the fossils do not belong to recent species.

Gyrogonites have not yet been observed in any deposit more ancient than the freshwater formations of the basin of Paris. Cyprides occur in the tertiary strata, and in the Weald clay below the chalk, and perhaps in the Birdiehouse limestone of the Edinburgh coal-field. Of the other five genera discovered in these fossil beds, two have hitherto been found only recent or in tertiary deposits, viz. *Limnea* and *Physa*; and the best characterized specimens of some of the others are referable to the same period. It is therefore extremely probable, that the basalt in which these fossils are imbedded, and which has altered the rocks in which they occur, belongs to the tertiary epoch; but to which period, I fear we have not the means of forming any decided opinion. Though none of the species are recent, yet they are too few and in

* See Plate XLVII. and Description.

too ruinous a state to admit of any general conclusions; although, from the very great number of individuals collected in various localities, without adding any fresh species, it is probable that nearly the whole which exist have been procured. But when the vast extent of the country occupied by the basalt is considered, and that a still greater tract was broken up or disturbed at the time of its eruption, it will not appear improbable, that a rule, founded on the disappearance of marine shells in districts exposed to no such extensive causes of destruction of animal life, should not apply.

In the preceding pages, I have described the fossils discovered by Mr. Geddes and myself in various parts of the Sichel mountains, and the Valley of Berar, extending through the great trap district for 140 miles; and I shall now shortly refer to other localities at great distances from each other, where the same fossils have been found in similar rocks, buried under the basalt.

Other Districts of India in which similar Freshwater Shells have been found.

Dr. Spilsbury discovered, eighteen miles from Jubalpoor, in an undulating plain studded with irregular masses of trap, blocks of "indurated clay," containing casts of fossil shells, for the most part siliceous, and resembling those discovered by Dr. Voysey in the Gawilghur range*. At Saugor, nearly 100 miles to the north-west, reversed shells, stated to be exactly the same as those of Jubalpoor, were discovered by Dr. Spry in a bed of limestone, entirely surrounded by an amphitheatre of trap hills, in which a lower range of compact sandstone is included†. This fossiliferous limestone is covered by 17 feet of basalt, and rests on a coarse siliceous grit, under which basalt is again met with. In the same neighbourhood fine specimens of silicified palms are found. Jubalpoor and Saugor are situated to the north of the Nerbudda, in the great Vindya range; and in the same district fossil bones of Mammalia occur in limestone capped by basalt. The drawings of the shells differ a little from each other‡, but the fossils are stated to be the same; and, as far as Mr. Sowerby could judge, they do not differ from the *Physa Prinsepii*. The similarity was more obvious in other specimens left in India, and I have no doubt of their being the same. It is, however, desirable that the specimens themselves, in the Museum of the Asiatic Society of Bengal, should be compared, that the connexion of the northern and southern portions of the trap formation may be placed beyond a doubt. South of the Nerbudda, fossils are again met with in the mountainous country, north of the sources of the Taptee, at a place called Jirpah, near to which trap hills have broken through the sandstone. Dr. Voysey, in speaking of the heat of the steel furnaces of Neermul, notices the occurrence of an "indurated clay" containing fossils at this place, but he gives no further information regarding them§. In a small specimen of this rock, Mr. Sowerby recognised the *Paludina Deccanensis*, and a portion of a larger shell, probably the *Physa Prinsepii*; and the matrix is the same as the fossiliferous "indurated clay" from Gawilghur; it also much resembles many of the varieties of chert in which the Berar fossils are found. The third range of hills has been described by Dr. Voysey under the name of the Gawilghur Mountains, and it forms a very remarkable feature in the physical geography of Central India. In

* Journal of the Asiatic Society of Bengal, vol. ii., p. 205. † Ibid., pp. 376, 639.
‡ Ibid., p. 583, Plate 20. § Journal of the Asiatic Society, vol. i., p. 247.

this lofty basaltic range, Dr. Voysey discovered fossil shells, the situation of which he has accurately described*; but as his account of them, has been so far misunderstood, as to induce Mr. Conybeare to state that they occur in "lias-like beds†," and Colonel Sykes in a recent deposit‡, it is necessary to mention that they are found in mountains in great part composed of basalt resembling that of the Giant's Causeway, but containing, more frequently, crystals of olivine, of basaltic hornblende, and carbonate of lime. This rock passes into a wacké, having every variety of structure and induration known amongst trap rocks, or into what has been called stratified basalt, from the parallelism of its planes, "the summits of many of the ravines presenting a continued stratum for many thousand yards§."

Ascending from the Taptee river, Dr. Voysey‖ observed a group of basaltic columns, and near the summit of the flat table-land of Jillan, he entered a pass presenting a perpendicular section, above the road, of 30 feet, and below it, a rapid descent of between 40 and 50. The lower part of the section, as well as the pathway, is composed of wacké, and "lying on it, is a stratum of earthy clay of different degrees of induration, 20 yards in length and about 2 feet thick, containing a great number of entire and broken shells," which are much compressed, and do not effervesce with acids. Some of them completely commix with the matrix. This bed of clay possesses all the characters of a stratum, which Dr. Voysey says, seems to have been depressed by an overlying mass, 15 feet thick, of the nodular basalt or wacké so common in these hills. The vertical fissures, which are so "remarkable in trap rocks, are prolonged from both the upper and lower rocks, into the shelly stratum, although there is no intermixture of substance." The stone in which these fossils occur, is similar to that of Jirpah, and of many of the specimens from the Sichel range and the valley of Berar; and the casts and fragments of the shells resemble those of the Paludinæ and other shells of that district. Between these mountains and the Sichel hills, the great valley of Berar is included, but the two ranges closely correspond in the nature of the soil and rocks, and in their fossiliferous beds. They are not, however, exactly parallel; nor do I think, that we are justified in classing them with the Vindya range to the north of the Nerbudda, or with the range which separates the valley of that river from the valley of the Taptee.

It is evident, from the same fossils being found in all these ranges, several hundred miles distant from each other, and from the same secondary rocks being broken up and altered, that the basalt of which they are principally composed was, in part at least, erupted at the same time; and that the western and eastern ghàts must have partaken in this great movement.

Shells, probably of the same genera, were also found by Dr. Voysey in the insulated basaltic hills of Medcondah¶ and Sivalingapah, which rest on the granite of the Deckan, south of the Godavery, and are probably connected with the southern part of the great trap district, and the hills of Bicknor Pett and Nugger shown in Section 1., Pl. XLVI. The fossils are imbedded in the basalt, in a siliceous rock containing lime, and corresponding in specific gravity, chemical com-

* Asiatic Researches, vol. xviii., p. 187. † Report to the British Association, 1832.

‡ Geol. Trans., 2nd Series, vol. iv., p. 426. § Dr. Voysey, Asiatic Res., vol. xviii., p. 127.

‖ Asiatic Researches, vol. xviii., p. 192, and Journal of the Asiatic Society of Bengal, vol. ii., p. 304.

¶ In a specimen of this chert in the Geological Society's Museum, I have found a gyrogonite of the same kind as those of Nirmul, and halves of a species of *Cypris* associated with shells. June 24, 1839.

position, and appearance to the fossiliferous cherts of the Nirmul Hills. Sivalingapah lies considerably to the west, but nearly in the same latitude as Nirmul.

The only other locality where fossil shells have yet been discovered, within or near the great basaltic district, is five miles south of Rajahmundry, a large town on the Godavery, a little above the alluvial plains of its Delta*. They occur in some small hills ranging nearly W. and E., and composed of conglomerate and red sandstone supporting wacké, overlaid by limestone containing shells, which is again covered by basalt. The shells are in the best condition in the upper part of the limestone; of many only the impressions remain, but the oysters, which are the most abundant, are well preserved. The basalt and some specimens of the chert, jaspers, &c., from these hills, presented to me by Dr. Benza, resemble the varieties found with the freshwater shells of the Sichel range, and the hills in which they occur having the same direction, are probably connected with the eastern termination of that range. They are evidently associated with the sandstones of the diamond districts to the north of the Kistnah, and with the continuation of the eastern ghàts; thus confirming the opinion above expressed, of these mountains being of more modern elevation than is supposed by some geologists. It is impossible to separate the western ghàts from the eastern in any theory that can be formed, as they diverge from the same point, support the same table-lands and the same stratified rocks; and where these mountains meet at the Neilgherry Hills, the hornblende schist has been noticed by Dr. Benza to dip in opposite directions from the eastern and western mountains.

In the Journal of the Asiatic Society of Bengal, vol. iv., p. 565, and Plate XLVIII., fossil shells are figured, which bear considerable resemblance to some specimens of Unio from the Sichel Hills, but not sufficiently to identify them. They form part of the Dadapoor collection of Sub-Himalayan fossils, so ably investigated by Lieuts. Baker and Durand, and are stated by Mr. Prinsep, in a note, to be identical with specimens collected by Colonel Burney with the bones of the Mastodon, &c. in Ava. He adds, that they probably belong to the large and thick species of *Cyrena* noticed by Professor Buckland as occurring in a blue and marly clay near the locality of the fossil bones collected by Mr. Crawford (Geol. Trans., 2nd Series, vol. v.); but I found the specimens of these shells in the Society's collection, to differ both from those of the Sub-Himalayahs and of Central India.

Mr. Pentland, in the same volume of the Geological Transactions, makes the following observations on Indian tertiary deposits: "How far the same formation may be prolonged in a southerly "direction along the peninsulas of Malacca and of Hindoostan it is impossible to say; although "we possess proofs of its existence at Madras, where it contains the same species of shells as on "the Brahma-putra, and at Pondicherry, where it envelopes the great masses of silicified wood "found near that city." (p. 394.) The formation on which Madras stands is, however, erroneously referred to the tertiary epoch, being a recent alluvium, accumulated by the joint action of the rivers and breakers, and containing the same shells as now inhabit the mud of the salt-water inlets and sea shore of the Carnatic.

With regard to the age of the silicified wood of Pondicherry, no facts have yet been ascertained which can justify any conclusion. It is, however, to be hoped, that a gentleman familiarly acquainted with the tertiary and volcanic rocks of Greece and Italy, will soon communicate positive information regarding the geological relations of the sandstones containing the silicified trees and the fossil shells†, the conical hollows, obsidians, and other indications of volcanic action said to exist in that neighbourhood.

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* Dr. Benza on the Neilgherries, Journal of the Asiatic Society of Bengal, p. 435., Aug., 1835.

† The shells I have seen differ from those of Central India.

Relative Age of the Laterite and Trap.

I shall conclude this paper by one or two remarks on the relative age of the Laterite and Trap. Dr. Babington* and Dr. Christie had observed this rock, both below and above the ghàts in the latitudes of Seringapatam and Goa, and I have traced it in the deep and narrow valleys of Coorg, at various heights, from the level of the sea to several thousand feet above it; but as in all those places it rests on syenite or other granitic rocks, from the decomposition of which, *in situ*, there is much reason to suppose that this remarkable formation is derived, no inference as to its age can be drawn from these facts. At Colter, however, and other places on the coast of the great basaltic district, it rests on the basalt, forming the summits of the hills, or an external layer over the trap which constitutes the body of the hill. This superposition is exhibited in ravines passing through the laterite, or where that rock has thinned off so much, that it can be separated from the basalt below, which has most commonly a stratified arrangement, often highly inclined and parallel to the precipitous face of the hill. It has also been observed above the ghàts, and in the table-land of the Deckan, between the Godavery and Manjera rivers, resting on basalt; it is therefore probable, that the trap has been protruded from below since the laterite assumed its present form. It would be improper, in this place, to enter into any details regarding a formation which extends over much of the Malay peninsula, Ceylon, the coasts of Coromandel and Malabar, and Central India. In different portions of these vast countries, several varieties of this rock are met with, well deserving of attention, yet its general character and composition is the same over 30 degrees of longitude and 20 of latitude, and nowhere is any proof to be found of its being of volcanic origin†, or the equivalent of certain European rocks, as supposed by Elie de Beaumont. Under the name of laterite, however, very different rocks have been included; such as the ferruginous clays and sandy beds underlying the alluvium of the Irawady, near Rangoon, and a ferruginous conglomerate now forming in many places from decomposed and reconsolidated laterite or syenite, and containing fragments of granite, and occasionally enveloping a recent land shell.

Besides these, a rock, apparently of igneous origin, has been occasionally confounded with laterite, and in the diamond districts is known to the natives by the same name as is applied to that rock in the Mysore. The thinner strata of the diamond sandstone of the Pennar have been observed to be bent in a remarkable manner by the intrusion of this rock; and in other instances it

* Geol. Trans., 1st Series, vol. v., p. 329.

† Calder, Asiatic Researches, vol. xviii. Conybeare, Report to British Association.

had apparently escaped in a semifluid state between the joints of the larger tables, carrying with it fragments of the sandstone, whose angles are so well defined, that I thought I could trace the very spot from which they had been broken off. Notwithstanding these appearances, the character of the rock differed so much from any varieties of basalt I had then seen in India, that I hesitated about referring it to the trap family, till I had seen varieties of a red wacké much resembling it, constituting part of the basaltic mountains of the island of Salsette. It is in a substance of this kind, interstratified with sandstone, that Tavernier describes the diamond mines of Beejapoor to have been worked in former times. The transitory nature of the political divisions of this part of India, and the decay or desertion of many towns and villages, have hitherto prevented the identification of these mines; but enough has been said to show the importance of caution in reasoning on individual facts, relative to one of the most singular and extensive formations anywhere to be found.

Note.

The freshwater shells described in the preceding pages, must have inhabited sheets of fresh water of which no traces can now be discovered, in the configuration of the mountainous tracts, in which they for the most part occur. No natural lakes exist in these districts, nor could shells have accumulated in such quantity in rivers similar to those which now intersect the country. It may, however, be supposed that the sandstone and limestone rocks of Berar had once a position similar to that which the same rocks now occupy in the basins of the Kistnah and Pennar. Voysey describes these rivers as passing through the Nulla-Mulla range by gaps or fissures "which have been pro-"duced by some great convulsion, which at the same time that it formed the "beds of these rivers, gave passage to the accumulated waters of some vast "lakes situated near the outlets." "The tortuous course of the Kistnah is "bounded for upwards of 70 miles by lofty and precipitous banks, which in "some places rise 1000 feet above its level, the opposite sides of the chasm "corresponding in an exact manner. Ravines of this description are not un-"frequent all over the range, and the exact correspondence of their salient "and re-entering angles, together with the abruptness of their origin, totally "preclude the supposition of their being hollowed out by the action of "running water*." Such seems also to have been the case, where the Pennar passes through a narrow gorge in the Gundicottah sandstone hills. Through the upper part of its course, this river flows over a flat country co-

* Asiatic Researches, vol. xv., p. 123, 124.

vered with alluvial soil, at right angles to the hills; but it finds an exit through them, by a fracture in the wall which in former times had apparently dammed up its waters. The strata have been much disturbed, probably by the eruption of the basalt, which is seen at the foot of the sandstone hills on the opposite side of the valley, from which the Gundicottah range appears to have been separated. Pl. XLVI., Section 2nd. It should, however, be stated, that ravines formed in this sandstone, by the action of the streams now flowing in them, exhibit abrupt precipices, the opposite sides of which correspond to each other as Voysey has described.

The sections accompanying this paper were constructed by Capt. Smith, of the Madras Engineers, F.R.S., from information contained in my notes made during several journeys in the lines represented, and from some published papers. The information is by no means complete, but, I believe, it will be found to be correct as far as it goes. In consequence of the great length of the lines to be represented, and the comparatively moderate height of the hills, it would have been impossible to have given the different formations of sufficient size to have been seen in a distinct manner without great distortion of the strata, had the whole distance been represented. Breaks, therefore, have been introduced, representing the continuance of the same rock for the number of miles specified in each instance. In the Baulpilly valley and in some other localities (Sect. 2.) the summits of the hills are almost inaccessible, and it has consequently been impossible to represent them as they occur in the exact line of section. I have therefore been content to exhibit the strata as they occur at their bases, with the exception of a few of the hills which have been more carefully examined, and which correspond in appearance to those which are as yet unexplored.

Section 1st passes from the Bangnapilly diamond mines to the valley of the Nerbudda, with the view of connecting Section No. 1, across the peninsula, with a line running north and south through its centre; and which might easily be continued to the Himalayah mountains to the north and Ceylon to the south.

Additional note referred to in page 545.—"In a specimen in the Geological Society's Collection, taken by Dr. Voysey from a '*greenstone dike*' passing through granite, at Guntoor, south of the Kistnah river, olivine is diffused amongst the other constituents of the rock." June 25th, 1839.

XXXIX.—*Geological Notes on part of Mazunderān.*

By CHARLES M. BELL, M.D.

[Read January 17, 1838.]

TEHRAN stands on an alluvial plain consisting chiefly of *débris* of limestone and trap rocks. (see Map, p. 381.) The high range immediately to the north of the city is composed of fine-grained lithographic limestone*; the strata dipping to the north and resting upon porcelain-stone, which passes into serpentine and porphyretic claystone†. The hills to the south-east of Tehran and overhanging the ruins of the city of Rai, are formed of limestone reposing on trap.

From Tehran the soft, lithographic limestone extends nearly to the village of Demavend; but the sandstone of the subjacent coal-formation is occasionally exposed. A little to the westward of the village, the ground rises considerably; and in the ranges of mountains, both north and south of the road, as far eastward as the caravanserai of Dalee chaee, nothing is seen but limestone resting on trap. In the bed of the river, we passed some upraised strata of altered shale, resembling coked coal; and upon the opposite bank we observed a loose conglomerate of fragments of limestone and trap, imbedded in what appeared to be dried mud, or detritus of the above-mentioned limestone‡.

* This stone, which takes a beautiful surface, has lately been used in the lithographic presses at Tehran; and it forms an excellent cement under water. Associated with a blue variety it extends over an immense tract to the N. and N.W. of Tehran, on the southern aspect of the chain of Elboorz. It there generally rests upon shale and red sandstone, which again overlie a compact limestone. (This rock is considered by the author to be mountain-limestone.—Ed.)

† The rock which forms the substratum of the greater part of the range of the Elboorz is trap, passing into every possible variety of basalt, greenstone, claystone, claystone-porphyry, pitchstone, pitchstone-porphyry, serpentine, &c.

‡ From its appearance in different parts of the country, I imagine this formation to be the remains of great volcanic floods of mud, which carried along large fragments of rock, and were spread unequally over the surface; and that they have been more or less removed by denudation. In the present route, we met with it in several places, occupying low hills and valleys, in general unconformably with the strata beneath; and in other parts of Persia we found a similar formation covering the lower grounds, near lofty ranges of limestone elevated upon trap,—for instance, in the valley of the

Here I found portions of two small ammonites in fragments of a compact limestone*, but I know not to what formation they originally belonged.

Above the caravanserai of Ameenabâd, limestone, superimposed on trap, again occurs. The river Gazan-chaee runs through a great thickness of the loose conglomerate. The plain of Ferooz-kooh is amygdaloidal basalt; and the hills in the neighbourhood consist of limestone resting upon it; having, on some of their summits, more or less of the above conglomerate.

Leaving Ferooz-kooh, and passing the summit of the highest range of the Elboorz, we found to the north of the snow, shale and sandstone of a coal formation, resting upon limestone. At that point commences a deep fissure, through which the river Talâr flows, till it escapes into the plain of the Caspian. At Abbassabad the ravine opens a little, and discloses sandstone; but the river is soon again confined between precipices. The sections of strata, however, on the opposite sides show very little resemblance.

A small stream entering on the right bank deposits much calcareous sinter and what is called oriental alabaster, an imperfectly crystallized calcareous spar.

Below Pul-i-Suffeed the rocks are chiefly conglomerates, formed from the *débris* of the mountains, and united by a calcareous deposit. Where the summits of the adjacent mountains were visible, they appeared to be composed of limestone.

As we still descended the stream, the stones forming the conglomerate became smaller, rounder, and more firmly cemented, including rolled pebbles of quartz and granite, and minute fragments of shells, probably the remains of an ancient sea beach.

For a considerable way, the river flows at the bottom of an exceedingly deep and narrow gorge, which divides perpendicularly thick beds of conglomerate and limestone, the road (Shah Abas's causeway) leading along the face of the precipice, many hundred feet above the stream.

It is remarkable, that we owe the preservation of this important and almost only remaining portion of that great work, to the firm manner in which the calcareous dripping from the mountain-side has cemented the stones together.

Below Sheergâh the country becomes open and the soil deep and clayey;

Kezzleoozen, east of the Kaflan Kooh, in the valley of Shah road, under the hills of Alamoot, and between Tabreez and the Schund range.

* I found a compact shell-limestone, containing bivalves, on the summit of the ridge of the Elboorz, just below the snow-line, south of the district, Toonikabān in Mazunderān; and another limestone, containing oyster-shells and madrepores, overlying sandstone, near Bayazeed, in the neighbourhood of Mount Ararat; but they are both probably more recent than that which contains the ammonites. As yet I have found no fossils either in the lithographic or compact (mountain) limestones.

and, passing Aliabad bazaar, we met with nothing but mud and jungle, till we reached the Caspian.

Along the shore of this sea are innumerable trunks of large trees, half imbedded in the mud and sand of the beach, and brought down, in time of floods, by the numerous rapid rivers which flow from the richly-wooded ravines of Mazunderān, Ghitan Talish, Carabaugh, &c. If I may judge from the number of trees which I saw a single river hurrying down its torrent in the spring of 1839, the quantity of wood annually carried into the Caspian must be enormous.

The waters of this inland sea, near the shore, are so fresh, that a horse does not refuse to drink them. The shells on the beach are chiefly fresh-water helices, cockle-shells, &c.

There is a high and low water-mark on the shore, not the effect of tides, but produced either by the occasional set of winds, or from the basin of the Caspian being fuller at one season than another, in consequence of rains or the snows melting on the surrounding mountains.

The sea is evidently fast filling up; and so great is the quantity of mud brought down by the rivers in spring and autumn, that it is easy to trace their discoloured waters five or six miles from the land; and so shallow is the Caspian near the shore, that ships of 120 tons burden, coming to the coast of Mazunderān, are obliged to anchor at the distance of two or three leagues.

Leaving the alluvial plain of Mazunderān, and ascending from Amol, the bed of the river Heraz, the road again enters a ravine in well-wooded mountains composed of sandstone strata resting upon limestone. As we proceeded, the limestone was exhibited overlying claystone porphyry. Thence, as far as Karoo, the rocks appeared in the sections in the following order: trap—limestone—sandstone—shale and indurated slate-clay—Buhr-stone—then sandstone, limestone, trap.

On the tops of some of the hills, there is much loose trap-rock rapidly undergoing decomposition.

At Karoo is a breccia similar to that at Dalee chaee. The bend of the river between Karoo and Bulkulum is in a narrow, deep fissure through a mountain of limestone, with a few strata of coal and sandstone distinguishable on the top of the precipice.

On this line of road are many ruined bridges, and portions of broken masonry; also remains of roads, now impassable; but, in this narrow fissure, the ruins of a stone bridge were too remarkable not to attract attention. The piers, built on the solid rock of the opposite sides of the river, seemed as if they could never have been intended to support the same arch, so different was

their parallel. Upon inquiry, I found that this, like almost all the bridges and galleries on the road, had been destroyed (and the opposite sides of the ravine had no doubt suffered displacement) by a tremendous earthquake, which occurred about eleven or twelve years before, and destroyed an immense number of villages, and rendered the road totally impassable for nearly two years. On the more eastern line of route, we saw the destructive effects of the same earthquake, in the almost total ruin of the caravanserai of Jajerood, the ruin of a handsome mosque at the village of Demavend, and the destruction of other buildings, as far as Sarree.

As we advanced, the ravine opened a little, and, about a mile below the village of Bulkulum, a lofty hill, rising in a precipice of 900 or 1000 feet from the water's edge, presented a fine section of perpendicular beds of coal, of which, together with a few strata of sandstone, the whole hill is composed. On the right or opposite bank, the sandstone strata are nearly horizontal.

For five or six miles above this place, the strata are often most curiously disturbed, and twisted in every direction. At one point on the right bank, a section showed the sandstone and shale bent to within a few degrees of completing a circle.

Below the Abi Noor, a stream running in a small valley which opens to view the peak of Demavend, the before-mentioned loose breccia occurs—and higher up is sandstone; while at Usk, and a little below it, calcareous tuff from hot springs covers every thing. The temperature of one large sulphureous spring, two miles E. by N. of Usk, and bubbling up from the summit of a hill of calc tufa, was 84° of Fahrenheit, that of the air being 48°. The inhabitants say, that there are many hot and cold medicinal springs in the neighbourhood of Usk, and that there is one of perfectly pure and tasteless water about three miles off, on the side of the mountain Demavend, hot enough to boil eggs. Half-way up the mountain, sulphur is stated to occur in great abundance and purity.

From one of the hot springs in the little capital of Usk, I procured some small, rough, siliceous globules, which are deposited in number by the water; and I have been told, that in Khorasān, where similar siliceous globules are formed by the hot springs, the inhabitants sort them, and use them as shot.

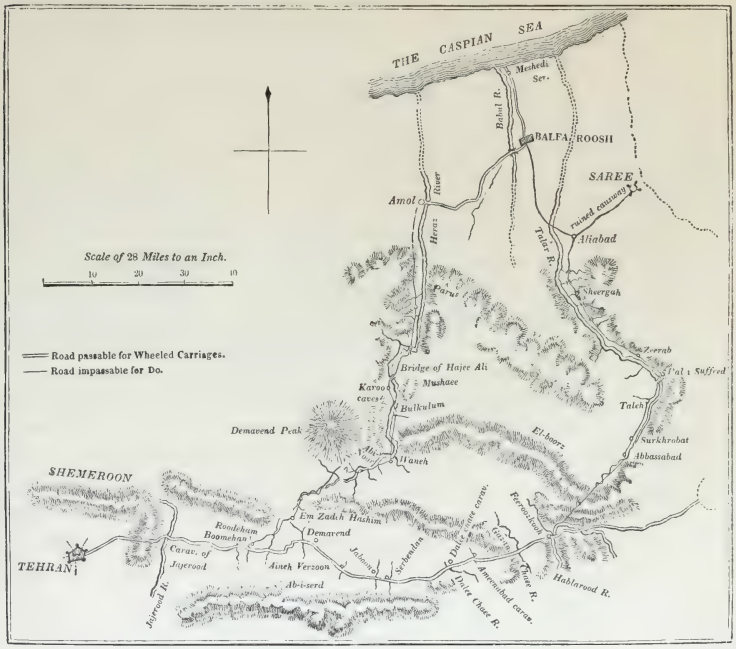
Above Usk, the river runs in a deep rent in greenstone. The first streamlet which flows into it, from the direction of Mount Demavend, is loaded with iron derived from the iron-shot greenstone; above which, there appear to be other, softer iron ores.

The greenstone continued till we arrived near the tomb of Em Zadeh Hashim, where it gradually passes into claystone, and underlies limestone. The

neighbouring hills, surveyed from this height, appear to be all composed of limestone resting on trap. Here our circuit ended.

I have only further to remark, that, from the top of the range down to the alluvial plain of Mazunderān, there is little in the course of the two rivers, the Tatâr and the Heraz, which can be attributed to the mere action of running water. Both ravines, especially that from Demavend to Amol, are continuous rents from the top to the bottom of the range; and, narrow though they be, it would be difficult to point out a single spot, where a correspondence of the strata on the opposite sides of the ravine exists. They have evidently been shifted by the successive convulsions which have elevated the range; an agent which we have seen to be still in operation.

I gave up as hopeless all attempts to note the angle and direction of the dip of the strata, as they vary continually, and, on the opposite sides of the river, I may almost say, never correspond. I am thus forced to content myself with stating the general direction of the dip to be north somewhat east.



Tehran, July 30, 1837.

XL.—*On the Geology of part of Asia Minor, between the Salt Lake of Kodj-hissar and Cæsarea of Cappadocia; including a brief Description of Mount Argæus.*

By WILLIAM J. HAMILTON, Esq., Sec. G.S.

[Read February 21, 1838.]

PLATE XLVIII.

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Account of Mount Argæus, and surrounding district, p. 594.

INTRODUCTION.

IN several papers communicated to this Society, Mr. Strickland has described the geology of some of the portions of Asia Minor, through which we travelled together in the early part of 1836. When circumstances compelled that gentleman to return to England, I determined, notwithstanding the greatly diminished interest of solitary travelling, to remain in Asia Minor, and to endeavour to work out some of the principal objects which we had in view, when we quitted England. Two of the most important of these objects,—a minute examination of the geology of the Catacecaumene, and the ascent of Mount Argæus, besides others of similar interest, I accomplished during the summer of 1837. I propose, therefore, in the following remarks, to give an account of the most eastern part of Asia Minor, which I then visited, and of Mount Argæus, the summit of which had never been reached by any European traveller; but I much regret, that my observations were not nearly so perfect as they would have been with the assistance of Mr. Strickland, whose knowledge of various branches of Natural History had been of the greatest use during our previous journeys.

In offering to the Society, the following account of the geology of that part of Cappadocia, which extends from the great Salt Lake of Kodj-hissar, eastwards as far as Cæsarea and Mount Argæus, I prefer describing the phenomena in the order in which they came under my observation, to giving a ge-

neral notice of the geology of the country, because, not having traversed it in many directions, it is impossible for me to define exactly the limits of the different formations. I intend, also, to confine myself to a mere description of the facts really witnessed, leaving to others the task of drawing conclusions respecting the geological epochs, during which the events may be supposed to have taken place.

I shall therefore describe, first, the country from the foot of Hassán Dagh, situated a few miles S.S.E. of Akserai, to the Salt Lake of Toozla or Kodj-hissar, as it is called in the country, a distance of about forty miles in a N.W. direction; and, secondly, the country from the Salt Lake eastward to Cæsarea, and the remarkable mountain of Argæus, or Erjish Dagh, a distance of about 108 miles.

Description of Hassán Dagh and the country between that mountain and Kodj-hissar.

The town of Akserai is situated in Lat. 38° 19′ N., and a little to the eastward of the 34° of East Long., and near the eastern extremity of a wide, flat valley, which extends from Hassán Dagh to the Salt Lake. On the south, this valley is bounded by low undulating hills, formed of the horizontal calcareous lacustrine deposit, which occurs so extensively in the central part of Asia Minor, and which stretching away to the west, are gradually lost in the great plain, having an almost imperceptible dip towards the same point. The hills on the northern side of the valley, at the foot of which Akserai is situated, consist of alternating beds of red and yellow sandstone, conglomerate, sand, and marl. The pebbles contained in the conglomerate are chiefly greenstone, trap-rock, quartz, sandstone, and limestone. The strata dip slightly to the S.W., and are much worn into sharp ridges, narrow peaks, and deep ravines. To the east and north-east they are capped with a remarkable, horizontal rock, which I shall presently describe*.

Hassán Dagh is a peaked mountain, rising almost directly from the eastern termination of the great horizontal calcareous plain which stretches past Akserai to the south. Its height I estimated to be upwards of 8000 feet above the sea. When I was there (July 10th) much snow still lay in the ravines near the summit on the northern side. The mountain consists entirely of trachyte, and trachytic, and porphyritic conglomerates. (Pl. XLVIII., Section 4.). Several volcanic cones, composed partly of trachytic conglomerate, and partly of scoriaceous matter, rise near its foot on the S.S.W. side, stretching away

* The range of the barometer during nearly five days that I was at, or in the neighbourhood of Akserai, was from 26·475 to 26·575,—my other barometer, registered at Smyrna, varying during the same period from 29·910 to 30·000 inches.

S.S.W. towards Karabunar and Karajah Dagh; whilst many others of a similar character encircle its base to the N.W., extending towards Akserai. Those on the N.W. side are all in the present valley, and, with the exception of one which, although higher up the slope of Hassán Dagh, appears to belong to the same formation, are considerably below the horizontal beds of trachyte which cap the hills on the north side of the valley, and which stretch away N. and N.E., thereby proving their recent origin, which must have been subsequent to the scooping out of the valley between Hassán Dagh and the hills to the north. From one of these cones a very considerable stream of black vesicular lava has flowed for some distance into the plain towards Akserai, and encircled some of the smaller cones, which stand at a lower level. On the summit of several of these conical hills (or Puys), slight depressions are visible, but they are scarcely deep enough to justify their being called craters.

The hills which form the northern boundary of this valley, are about 300 feet in height, and are capped, for some distance, with a white pumiceous rock, the stratification of which is either horizontal, or dips almost imperceptibly towards the north. The surface slightly undulates, and the edge or scarp of this table-land is much indented and broken. This pumiceous rock immediately overlies the red and yellow sands and sandstone conglomerates. Near the point A, in Section 4, I obtained the following section of the different beds in an ascending order, the whole thickness being about sixty feet.

A.—A soft whitish yellow pumiceous peperite or volcanic sand, about eight feet thick. It decomposes and is easily washed into large caves and cavities, in consequence of which the superincumbent beds have fallen down, and large masses of them cover the S.W. side of the hill for some distance.

B.—A similar rock, but much harder and more compact; about 12 feet thick. A very distinct line separates these beds.

C.—A soft pumiceous sandstone resembling A. The upper portion of this bed differs considerably from the lower, apparently in consequence of its being overlaid by a rock which was probably deposited in a more incandescent state. The upper portion is full of long narrow nodules of a much harder rock, striking downwards from the surface of the bed, and varying much in length. They effervesce with acids, and as the matrix does not contain calcareous matter, they were probably formed by the aggregation of the lime, in a manner similar to that which has produced septaria in other formations. The thickness of the bed is four or five feet.

D.—A brecciated rock, containing numerous angular fragments of coarse pumice stone. This and the two overlying beds have a closeness of grain and almost viscous and semicrystalline appearance, which renders it difficult to determine, whether they are due to volcanic sands which were deposited horizontally under water, or whether they are trachytic beds, closely resembling some of the domites of central France, which flowed from a subaqueous crater and were spread over the bottom of an ancient sea or lake.

E. and F.—The lower of these beds is a soft, purplish white, trachytic rock, and passes upwards insensibly into F, which is harder and generally whiter. They both contain zeolites and crystals of olivine and hornblende, and apparently a few plates of mica.

The cliff of this table-land presents, in many places, slight indications of perpendicular cleavage, but the lines are not sufficiently marked to warrant the rock being considered columnar. The slope of the hill below the cliff, towards the W. and S.W., is covered with enormous masses of the upper, harder beds, which have fallen in consequence of the crumbling of the softer sandstone below. They extend to some distance, and as many of them have been derived from the very centre of the mass, they show the real structure of the beds much better than specimens obtained from the summit of the hill, where the rock has been long exposed to atmospheric influences.

A little to the east of Section 4, are very large fragments (in some places quite *en masse*) of the capping of the table-land, as if broken and let down by an earthquake or some great subsidence of the valley.

Still further eastward, the valley is suddenly terminated by a hill, or mass of very coarse trachytic and porphyritic conglomerate, stretching across from Hassán Dagh to the north; and it will be seen by Section 1, that the red and yellow sandstones and conglomerates repose upon this trachytic conglomerate, which, therefore, belongs to a much more ancient volcanic eruption than the white pumiceous capping just described. Notwithstanding the present apparently exhausted state of the great volcanic mountain Hassán Dagh, what a variety of epochs of activity, extending through a period the duration of which it is impossible to calculate, is laid open in the few preceding observations!

1stly. We have the epoch when these huge trachytic bowlders were thrown out; and whether they were brought into their present situation by direct ejection from the crater, or were washed down by currents from the breakings up of pre-existing trachytes, they bear witness to very early volcanic operation as respects this part of the globe.

2ndly. The epoch when the red and yellow sands and grits, and sandstone conglomerates, and marls were deposited upon these trachytic conglomerates, —a formation which, without attempting to fix its contemporaneity, I consider as nearly equivalent to our new red sandstone; at all events it belongs to the saliferous deposits of Asia Minor.

3rdly. The epoch when the extensive volcanic capping of the table-lands was poured or showered forth from the neighbouring mountain. This makes the second period of volcanic activity. It is impossible to state the extent of this formation, which ranges solely towards the N. and N.E.; I believe it may

be traced to the very foot of Mount Argæus, although it cannot be supposed that the whole of the volcanic matter has been derived from Hassán Dagh.

4thly. The period when the valley between Hassán Dagh and the table-land was hollowed out; and

5thly. The period (which is the third of volcanic activity) when the numerous cones at the foot of the mountain were produced, and from one of which a stream of black vesicular and scoriaceous lava has flowed. This is a period comparatively modern, and subsequent to the time when the surface of this portion of the earth had assumed its present configuration.

Notwithstanding the constant melting of the snows on Hassán Dagh, I was surprised at not finding a single stream flowing down its side. At the head of the valley, however, a rapid rivulet rushes along a deep and broken ravine from the eastward, through the mass of trachytic conglomerate, which forms the termination of the valley of Akserai. This stream issues from a deep and narrow lake situated amongst the low hills of trachytic conglomerate, close to the northern foot of the mountain, and is supplied from many copious springs which rise at the foot of the mountain, in the village of Khalvardere. It would appear that, as the snow melts, the water is absorbed by the porous volcanic rocks, and percolating through them, emerges at the foot of the mountain in the beautiful springs of cold sparkling and filtered water.

The hills of red and yellow sandstones and grits, which rise to the north of Akserai, and form the northern boundary of the valley, extend in a north-west direction to the shores of the Lake of Touzla or Kodj-hissar. A considerable river, called the Beas Sú (White Water), issues from a deep gorge directly behind the town, and flowing W.N.W. through the plain, is ultimately lost in the flat saline marshes, which form the eastern boundary of the Salt Lake. Owing to the nature of the country and the want of fresh water, it was impossible to examine these hills, as I might have done at a different season; and the road through the plain is generally four or five miles from them. They appeared to consist of the same formation the whole way. About twenty miles from Akserai, where they approach the lake, and between which and the hills the road passes along a narrow slip of low, half-cultivated land, I had an opportunity of more closely examining their structure.

They consist principally of a brown sandstone conglomerate, dipping nearly south; but several hard beds of conglomerate or grit, some of which contain much calcareous matter, are interstratified with softer beds of thinly laminated sandstone, slighlty micaceous. In some places, the sandstone becomes yellowish, and contains a few bands of indurated shales, the whole of which

evidently belong to the red sandstone formation*. These beds all dip to the south nearly 80°. From this locality, as far as the village of Kodj-hissar, the same red and brown sandstones and grits continue on the east side of the road, approaching in some places close to the lake. Further to the eastward, beds of red and white marls and sand dip under the red sandstone.

Salt Lake of Kodj-hissar and the neighbouring District. (Sect. 2, 3, & 7.)

The small town or village of Kodj-hissar is situated at the western foot of this range of hills; and a gently sloping alluvial plain extends westward as far as the Salt Lake, a distance of five miles (Sect. 7.). The water of this lake appears to be perfectly saturated. Fish cannot live in it, and if the wings of a bird touch it, they become instantly stiff and helpless from the saline incrustation; every piece of dirt or wood which falls or is thrown into the lake, is likewise almost immediately coated with salt. I was unable to ascertain the exact dimensions of the lake, but I was informed by the natives, that it is about thirty hours or leagues in circumference. From the spot where I examined it, at A. on the map, a gulf about five miles wide extends sixteen or eighteen miles to the N.N.W.; and I understood that to the S.W., where the lake is broadest, the opposite shore is eight or nine hours or about twenty-four miles distant.

The bottom of the lake is, in most places, a very deep, soft mud, incapable of supporting the slightest weight; but where I reached the shore, which is the spot whence Sultan Selim carried a causeway across the bay in an almost westerly direction, the bottom consists of a thick solid crust of salt, resting upon the soft mud. When I was there, the salt was covered with six or eight inches of water, but I understood that in another month it would be quite dry. I rode above a mile into the lake upon this salt crust, and nearly along the line of the ancient causeway, which is quite ruined. A few blocks of marble rising a little above the water, but thickly incrusted with salt, alone mark its direction. This passage is about half a mile in width. My guide pointed out a few holes in the salt through which a rider and his horse might sink into the deep mud beneath. I saw also a few smaller holes from which springs of water rose. They were probably fresh, as there is said to be a fresh-water spring on one of the small islands, about 15 miles to the S.S.W.

The same red and brown sandstones extend beyond Kodj-hissar to the W.N.W. (see Sec. 2.); but the inclination of the strata is there towards the

* I shall hereafter have an opportunity of describing the rock-salt deposits of Pontus, but I will now observe, that I never found an instance of rock salt interstratified with these red sandstones.

N.W. or N.N.W., instead of the S. and S.W. This anticlinal dip is occasioned by a mass of fine-grained grey granite, which rises in the Castle Hill, immediately behind Kodj-hissar. (Sect. 3 and 7.) The granite penetrates the sandstone, sending forth veins or filaments, which gradually thin out. Further eastward, there appears to be a still greater mass of granite, also of posterior origin to the red sandstone.

About a mile N.W. of Kodj-hissar and at the very edge of the plain, I found some detached portions of the horizontal white limestone, which forms the central plain of Asia Minor. They rest unconformably against the sloping sides of the sandstone, and in some places fill hollows in the rugged surfaces of the upturned edges, (Sect. 2 & 7.); in others they even cap the hills on each side of the valley which opens to the eastward, a short way to the north of the village. The hills immediately behind Kodj-hissar consist of brown and yellow sandstone, shale, and grit, some of the beds of which are extremely hard, while others are conglomeratic. The general dip is towards the N.W. 20° or 25°, but in consequence of the protrusion of the granite, the beds are much disturbed; in one place, however, they were almost horizontal. The principal rock consists of a greyish brown grit, and soft brown laminated sandstone. Where it is in contact with the veins of granite, it is much hardened and slightly altered. In some of the upper sandstones of these hills, I found thin layers or bands of gravel and loose pebbles, amongst which were some resembling the grey granite just mentioned. It would, therefore, appear that all the granites of this district do not belong to the same period. On some of the sandy shales and lamellar sandstones, I observed slight impressions, like those of fucoid stems in the shales of the coal-measures, or the Alpine limestone near Trieste.

Before leaving the district of the Salt Lake, I would mention the remarkable coincidence, that the extensive beds of rock salt on the borders of Pontus and Galatia, which have been quarried from the time of Strabo until the present day, occur in a precisely similar formation. I visited them in 1836, and found troughs or small basons of rock salt horizontally stratified, resting upon the perpendicular upturned edges of red and brown sandstone conglomerates. The strike of these vertical beds is from N.E. to S.W., and as far as I could judge they are situated directly N.E. from Kodj-hissar, and consequently the Salt Lake is in the direct prolongation of their strike. I have but little doubt, that the formation is continuous from one locality to the other, or almost half across this part of the peninsula of Asia Minor; and I was also told, that other mines of rock salt (Kaiya touz maden) occur in the intervening district.

I will now describe the formations which I observed between the Salt Lake of Kodj-hissar and Cæsarea, situated at the northern foot of the trachytic mountain of Argæus.

Country between Kodj-hissar and Mount Argæus. (Section 7.)

A very gently rising alluvial plain extends from the Salt Lake almost to Kodj-hissar. At the foot of the hills near that village, the horizontal beds of white limestone rest, as before described, unconformably upon the red and brown sandstones, and immediately to the eastward occurs the granite mass which, rising up through the sandstones, has produced the anticlinal dip of the strata. About three miles east of Kodj-hissar is an extensive table-land composed of the horizontal white limestone, but it is at a very much higher level than the beds at the village, and it rests upon brown sandstone and sandstone conglomerate, containing much selenite, which also occurs upon the surface or mixed up in the soil. Interstratified with the sandstone was a thick bed of milk-white fine-grained or compact gypsum. Hills of soft laminated sandstone, apparently of the same formation, continue, for some miles, to a range of high rugged mountains of grey granite resembling that of Kodj-hissar, and extending in a S.E. direction for nearly thirty miles. Before reaching these hills, the ground was covered for some way with boulders of the granite and a large-grained porphyritic trachyte, derived from some rugged hills to the north.

My road led along the northern slope of these granite mountains, and in the distance, to the north, I could clearly distinguish successive ranges of hills which, from their colour and stratification, evidently belong to the red sandstone formation. These granite hills are strikingly distinguished from those composed of trachytic rocks, by the numerous springs, which burst forth on their northern slope; but the water is soon absorbed by the sandy soil which covers the declivities of the hills, derived from the disintegrated granite.

Twelve miles from Kodj-hissar a trap or claystone porphyry dyke crosses the road, stretching nearly N.E. and S.W. or N.N.E. and S.S.W. The granite in contact with the dyke is reduced to a state resembling Kaolin. Several ridges of granite extend to the N.E. from the principal chain.

To the north-east of these hills is an extensive, alluvial plain, through which a stream flows, in wet weather, W.N.W. into the Salt Lake ; but the channel was dry, when I was there. After crossing this plain, the road leads along the N.E. side of a gradually narrowing valley, which is bounded on the S.W. by the above-mentioned grey granite, and on the N.E. by trap and other igneous rocks. Near the commencement of the valley, I crossed an extensive, insulated table-land, composed of an horizontal bed of volcanic tuff or peperite, capped by another of the same material but much harder. In the softer bed, numerous caverns have been excavated, leaving the hard stratum for a roof.

Descending again from this table-land into the valley, several protruding masses of greenstone or serpentine were observed in the line of section, and

they are probably connected with the hills to the N.E., which rise up to the north of Sarikaraman. Following the valley, we came again upon horizontal beds of tertiary limestone, but less pure than at the places before mentioned, and sometimes approaching to a nodular or concretionary structure. These beds rest against a red granite consisting of quartz and feldspar, which forms the termination of the valley, and stretching across from north to south connects the two ranges of igneous rocks, and may be said to mark the watershed between the Halys and the Salt Lake.

Beyond this granite are other protruding masses of trap and greenstone; and further on, the ground slopes gently to Tatlar, and is covered with large angular fragments of basalt. At that village a deep ravine exhibits a good section of horizontal beds of light-coloured tuff, or pumiceous sand, of considerable dimensions, covered with a thick capping of black basalt, slightly and irregularly columnar, which forms an extensive table-land, stretching away far to the north and east. This basalt is very vesicular in places, and almost as rugged on the surface as a modern stream of lava. It appears to have issued from one of the two lofty craters to the eastward, which are covered to a great height with loose scoriæ, cinders, and ashes. Other volcanic cones are visible to the south-east, from which streams of lava or basalt have also issued. Nor have all the igneous products of Tatlar been derived from one eruption. To the south-east of the village, and a little higher up the ravine, is a stream of lava, much more recent than that which forms the table-land to the east and north of the village; for it has not only flowed at a much lower level, but is seen in one place at the foot of the steep escarpment of the older basalt; its surface also is considerably rougher. It flowed in some places over the more ancient rock, and escaped through a narrow gorge or opening in the cliff into the plain below. This is visible a short way down the valley to the north of the village. Still the stream is so old, that the river has worn a way round it to the south-west, leaving a low cliff of tuff, also capped with basalt.

The other volcanic cones, to the south-east, have shallow circular depressions on the summit. In front of the most northern one, is said to be a small lake of brackish water; but no salt is obtained there.

The salt mines of Hadji Bektash are stated to be nine miles to the N.N.W., and to be very deep. The hills, amongst which they are situated, consist apparently of red marl and sand; and are beyond the several table-lands capped with basaltic plateaux, which extend four or five miles to the N. and N.N.E., and appear to belong to the same system as the basalt of Tatlar.

In the ravine, near Tatlar, are a few of the remarkable conical hillocks which occur in great numbers further east, in the vicinity of Urgub. They

form one of the most striking features of these valleys, which have been excavated in every direction in the volcanic pumiceous sand, to the depth of three or four hundred feet, by weathering and the action of water.

To the eastward of the volcanic cone, whence the basalt of Tatlar flowed, another table-land of cellular basalt extends about a mile, to the deep ravine of Alajahscheher, the castle of which stands upon the edge of the basaltic cliff. The basalt on the west side of the ravine overlies the horizontal pumiceous tuff, which differs from that of Tatlar only in being of a pinker colour, and in consisting almost entirely of pumice, but containing, in some of the beds, numerous small fragments of black obsidian.

Thick beds of this tufaceous deposit, varying in hardness, continue, with occasional exceptions, almost the whole way to the foot of Mount Argæus. But the compactness or hardness of the beds increases considerably near the trachytic base of that mountain, from which they are separated by a narrow and irregular plain or valley.

A few miles to the eastward of Alajahscheher, and before reaching Nembscheher, a mass of red trachytic rock rises to a considerable height through the pumiceous tuff, which appears to have been quietly deposited against it, as the tuff presents no trace of having been upheaved from its original horizontality.

A short distance from Nembscheher, a deep ravine exhibits a section of red and yellow marls underlying the pumiceous deposit, and dipping considerably to the south-east. The marls contain many veins and masses of white fibrous gypsum, the whole of which must have been disturbed previously to the accumulation of the tuff. I have already mentioned that selenite occurs in the red sandstone and marls near Kodj-hissar, to which formation these marls ought also to be referred, as well as the red sands beyond the volcanic table-lands to the north. In a deep ravine to the north of Nembscheher several beds of basalt, alternate with the tuff, and were probably derived from some high hills to the south. Basalt also occurs in the bed of the torrent which flows down from these mountains, on the east side of the town.

The same tufaceous rock, in horizontal beds, extends from Nembscheher to Urgub; at which place, and at Utch-hissar, half-way between the two, it has been excavated into deep valleys, by weathering and the agency of two small streams. From the unequal manner in which the rock has been acted upon, the most extraordinary phenomena have been produced. From the edge of the plateau of Utch-hissar (Pl. XLVIII., fig. 5.) we looked down upon a deep valley, in places three or four miles wide, and filled for several miles up and down, with an infinite number and variety of sugar-loaved cones, from 150 to 300

feet high, and for the greater part perfectly isolated from the sloping sides of the valley, but generally connected with each other at the base. Many of them have been excavated, and have served either as tombs to the ancient Greeks, or as chapels to the Greeks of the Byzantine empire. They are now used for dove-cotes by the Turks and Greeks.

In some places these cones occur on the sides of the hills, and present every variety of size, gradually increasing in height, from the first embryo near the summit, until, in the valley below, they stand out by themselves in full perfection and independence. At Utch-hissar the beds incline very slightly towards the north-east, and consequently the cones, which generally occur in the same beds, have a much lower level in that direction than at Utch-hissar itself. Looking down upon them from near the village, or at the distance of two or three miles, they appear so slender, and are packed so close together, that they resemble rather a forest of lofty cypresses than what they really are.

At Urgub, I observed a peculiarity in some of the cones, which I had not noticed at Utch-hissar. At that place many of them are capped by a large mass of a much harder stone, projecting like the head of a mushroom, the protecting influence of which has no doubt preserved the subjacent conical mass from the action of the weather. Although the mode of formation is not so apparent amongst the cones of Utch-hissar, there can be no doubt that they are also owing to some similar cause; and that the existence of a hard mass of pumice, or other extraneous substance in the tuff, resisted the wearing influence of running water or of rain, when the surrounding matter was washed away.

About thirty miles S.S.E. from Urgub, where the same tufaceous formation occurs, I observed, on the sloping side of a hill, numerous large blocks of peperite, which had fallen down from a much harder bed forming the capping of the hills. Wherever these blocks had rested upon the softer beds, they had protected the ground beneath them from the gradual wasting away to which the rest of the hill-side was constantly exposed; and under each of them might be seen the embryo commencement of a similar cone, varying from one to ten feet in height. They almost covered the face of the hill.

The beds near Urgub differ in hardness and tenacity, and in colour from pale yellow to white and very pale pink; but in one bed, the *lapilli* imbedded in it, were mostly coated by a black substance. In other places, the surfaces of the separate laminæ of the beds were covered with the same black substance. The extent of this pumiceous deposit from north to south is very considerable, particularly towards the south, in which direction, from the heights near Urgub, I observed it extending in regular plateaux or table-lands to a great distance.

A few miles to the eastward of Urgub, a considerable mass of trap or basalt

projects on the south side of the ravine, whilst on the north, the hills consist of indurated shales. Between the latter and the basalt, a stream has worn a deep passage, and a little further on, it flows over basaltic rocks, apparently interstratified with beds of coarse peperite, which dip S.E. about 40°. These volcanic strata are probably connected with the mass of basalt just mentioned, which appears to have been elevated through the red sandstone and marls. Large boulders and masses of jasper and flint and quartz resinite occur in many places in the valley, apparently derived from the beds of jasper and limestone on its north side; but I did not see any beds or nodules of flint *in situ*. These beds of jasper and limestone, which may perhaps be referred to the cretaceous period, or upper secondary formation, dip to the E.S.E. 20° or 30°. Beyond, we came again upon the horizontal tufaceous formation of which the hills consist, both right and left, as we ascended the ravine. Near Baktash the road and line of section leave the valley on the right, and wind up hills to the north, which in places have perpendicular escarpments forty or fifty feet high. On reaching the capping of hard tuff, which had been seen from below, I was surprised to find that the ground still rose gently to another plateau half a mile distant, formed by a thick bed of basalt, derived apparently from some high hills, a few miles to the E.S.E. The extent of this capping is not very considerable, but the ground to a great distance is covered with its broken fragments, caused by the gradual wearing away of the softer tuff beneath it.

Descending towards Injesu, which is situated on the same formation, the tuff becomes very hard, and separates easily into flags two or three inches thick. In a ravine S.W. from the town, is a junction of the hard trachytic tuff with the underlying red and yellow variegated sands and marls. The last near the surface are slightly indurated, and traversed by vertical fissures for a foot or two downwards. I could not ascertain their dip, and they appeared, as far as I could see, to be perfectly uniform, though variegated in colour, and to form only one bed, without separation, way-board, or intervening band of harder stone. Near the surface, however, the deposit contained a few pebbles and small boulders of volcanic rocks.

Mount Argæus and surrounding District.

From Injesu, the tufaceous formation continues for several miles, to the plain of Cæsarea. The vast insulated peak of Mount Argæus rises from that plain and sends out several prolongations and spurs to the north into the open country between Injesu and Cæsarea.

I call Mount Argæus insulated, because, although to the east its base is connected with another range of mountains, it rises on the north, the west and

south sides, perfectly free, from a vast level plain. On the west, indeed, the plain is narrow,as the mountain is separated from the hills of Injesu only by a flat valley one or two miles wide, down which a small stream flows in the winter, into the lake in the plain of Cæsarea. As I did not proceed up this valley, I cannot affirm that it is continuous the whole way to the plain of Kara-hissar, which is to the south of Mount Argæus; but I believe it to be so.

A short way from the first ridge of hills, which stretches down from Mount Argæus, the plain is covered with a thin saline efflorescence, apparently muriate of soda. This ridge, which is narrow and rugged, consists of compact black basalt, evidently one of the most recent *coulées* which have burst forth from the sides of the mountain. Between the ridge and the next mass of rock, a porphyritic and feldspathic trachyte, numerous springs of water rise and flow north into the plain. They are derived from the partial melting of the perpetual snows and glaciers on the summit of the mountain, the water having percolated through the porous rock.

The remaining formations, which the section crosses as far as Cæsarea, are trachytic, more or less compact, and more or less conchoidal in fracture. They vary in colour from dark gray to brown and dark red, and contain numerous imbedded masses of carbonate of lime. Near the summit of Yelanli Dagh, a little off the line of section, is a very deep and rocky crater, near the summit of a ridge, in many parts almost perpendicular. Towards the north-east, the sides of the crater have been broken away; but no trace of a lava stream can be seen extending from them.

Cæsarea is situated in the plain, at the foot of the lower hills, which slope down to the North from Mount Argæus. The diluvial soil near the town is much impregnated with nitre, which is worked and sent to Constantinople for the manufacture of gunpowder.

The plain extends from E.N.E. to W.S.W., and the hills which form the southern boundary consist for eight or ten miles N.E. from Cæsarea, entirely of hard, tufaceous rock.

Section 6 represents the hills at a spot nine or ten miles W.N.W. from Cæsarea, where the Karasú or Melas flows out of the plain of Cæsarea to the N.W., through a narrow gorge, into the Kizil Irmak or Halys. This section bears a great resemblance to the formations to the south, through which the general section passes, and consists of beds of white and yellow tuff or peperite, filling hollows and valleys in the pre-existing trachyte, some of the tuff being also capped with basalt. Lower down and near the river are a few horizontal beds of white limestone, which are probably of a much more recent origin, as they appear to rest against and overlie the tuff, although conform-

ably stratified. Lower down the valley, to the N.W., red and yellow marls underlie a white stratified rock, which is probably the white tuff mentioned before. This is another point of resemblance between the two localities, and it is probable, that, as in the neighbourhood of Akserai and Kodj-hissar, the red sandstone formation extends under this vast tufaceous rock throughout its whole extent. The most surprising and inexplicable feature in this phænomenon is the occurrence of horizontal tertiary and volcanic beds over so vast an extent of country, at the height of 4000 feet and upwards above the sea. What a mighty effort of elevation must we not suppose, capable of raising a tract of land above 200 miles in length to this great height, without anywhere disturbing the horizontality of the stratification!

About eleven miles due south of Cæsarea is the lofty summit of Argæus, rising like Hássan Dagh to a single peak, and bearing in its general appearance a great resemblance to the still more lofty peak of Ararat, which I had seen the preceding year. The summit of this mountain consists of a reddish brecciated and scoriaceous conglomerate, full of fragments of trap and porphyritic trachyte, and is nearly the point of junction of two enormous broken craters, one of which opens to the N.E., the other to the N.W., and the steep sides of which, to the north, are covered with perpetual snow for 2000 or 3000 feet below the summit. On the southern slopes the snow is not so deep, and except for the last 1000 feet, lies in the deep ravines only, and not upon the intervening ridges.

The height of Mount Argæus has hitherto been much underrated. Kinneir Macdonald guessed it to be only 8000 feet above the sea. The plain of Cæsarea is, by rough calculation of the barometer, at least 4200 feet above that level; and according to the three following observations, I consider that the summit of the mountain cannot be less than 13,000 feet above the sea.

By barometer	13,293
Angle of elevation from Greek Convent	13,242
Angle of elevation from Kara-hissar	12,809

A little below the summit on the S.E. side, rugged serrated ridges rise through the snow; consisting of a compact trachytic rock with a conchoidal fracture, resembling greenstone or hornstone. Other ridges are composed of trachytes of different colours and textures. Near the foot of the great cone several smaller ones of pumice and *lapilli* rise, encircling its base on the S.E. side, whilst to the west and north are many more, from some of which streams of basalt or lava may be traced; but I was unable to examine the whole of the mountain. Some of the cones of pumice on the south side have also deep depressions or craters partly broken away, and are clearly the most

recent proofs of igneous agency on this side of the mountain. On the southern flank I also observed, near the base, as I had before observed on the northern flank, several traces of streams of black basalt, which had flowed into the plain from near the foot of the mountain, and appear to have been partly buried by the gradual increase of soil brought down from the different mountains, and which, as there still appears to be no outlet for the waters, has a slow but gradual tendency to fill up and raise the level of the plain.

In concluding these remarks, I must express my regret, that the barrenness of the subject is increased by the general absence of organic remains from the great sedimentary formations of these tracts, and the consequent impossibility of referring the deposits to those of Europe, or to fix even an approximate scale of contemporaneity between them. In the red sandstone, I have never found the slightest trace of fossils, and but rarely in the white calcareous beds. In the neighbourhood of Sevri-hissar, W.S.W. of Angora, I discovered some beds which were near the top of this calcareous series, and were full of Limneæ and Planorbes, whence I conclude that it is a freshwater lacustrine formation.

Although the region offers evidence of volcanic action at many different periods, yet the igneous rocks are so rarely associated with stratified deposits, that it is almost impossible to ascertain, with any degree of precision, the geological era during which these events may have taken place. Nevertheless, we can clearly distinguish two widely separated groups of stratified rocks, and we have evidence of great volcanic activity between the two periods of their accumulation. The first or lower is the red sandstone, which is always connected with the salt districts of Asia Minor, and may, by analogy, be considered to be a secondary formation; and the second or upper is the horizontal white limestone, which, notwithstanding the violent convulsions to which most parts of this country have been exposed at various periods, has, with scarcely one exception, never been removed from its horizontality, and may be considered as a tertiary formation.

XLI.—*On some remarkable Dikes of Calcareous Grit, at Ethie in Ross-shire.*

By H. E. STRICKLAND, Esq., F.G.S.

[Read March 7th, 1838.]

I AM desirous of calling the attention of the Society to some remarkable dikes which penetrate lias schist at Ethie, near Cromarty. The beds of lias at this place have been described by Mr. Murchison in our Transactions*, and their relations are given in the accompanying wood-cut (p. 600). These beds are only exposed at low water, and dip towards the sea at an angle which gradually increases in approaching high-water mark, where they become perpendicular. Cliffs of gneiss and red conglomerate rise immediately from the shore, but the broken fragments which are scattered near high-water mark, conceal the actual junction of the lias with these older rocks.

The dikes, which are here seen to penetrate the lias, are remarkable for their mineral character, which so precisely resembles that of certain altered quartzose sandstones, that it is impossible to refer them to a purely igneous origin.

The substance of which they are composed, is intensely hard. On examining it with a lens, its component particles are distinctly seen, and bear the closest resemblance to ordinary water-worn grains of sand. The stone is penetrated by carbonate of lime, which produces a slight effervesence on the application of an acid; and it has assumed a pseudo-crystalline structure, which exhibits, when held in certain lights, the peculiar lustre of the calcareous sandstones of Fontainebleau and other places.

A careful examination of the locality sufficed to show, that however much this rock might resemble an aqueous product, yet that it forms genuine intrusive dikes, penetrating the lias shale in all directions. A and B are two dikes (see the wood-cut) which are parallel to the stratification of the lias shale, and their injected origin is not consequently immediately apparent; but C is a dike which sends off branches in various directions, and in no part of its

* Second Series, vol. ii. p. 308.

course is parallel to the strata which it penetrates. The thickness of this dike is about one foot, and that of its lateral offsets from three to six inches. D is the largest dike of all, being three feet thick, and ranging parallel to the shore for at least 200 yards. In one place, it also gives off a lateral branch, which extends a few yards and then rejoins the main dike.

These several dikes exhibit no variation whatever in their texture or composition, except being occasionally penetrated by small veins of carbonate of lime. They show no signs of lamination, but are frequently fractured transversely to their own direction. The transition is instantaneous from the dike to the lias shale, which seems to have suffered neither alteration nor contortion by the intrusion of this extraneous matter. The shale, from its greater softness, has been washed out between the dikes, leaving them to project like walls from one to three feet in height*.

I have been the more exact in describing this locality, because the identity of the specimens here exhibited with ordinary stratified sandstone is so perfect, that the clearest evidence was necessary to prove that they had been inserted into fissures of the lias subsequently to its deposition. The sedimentary structure of this rock forbids us to refer it to igneous injection from below, and notwithstanding the complete resemblance of these intrusive masses to ordinary plutonic dikes, we have no resource left but to refer them to aqueous deposition, filling up fissures which had been previously formed in the Lias. We have no clue to the period at which this insertion of sand into fissures of the lias took place, no fossils having been noticed in the substance of the dikes themselves.

In speculating on the causes of this phenomenon, we should bear in mind the total absence of trappean rocks on the eastern coasts of Ross-shire and Sutherland, and the presence of vast masses of granitic and syenitic rocks, which have been shown by Mr. Murchison to have been erupted subsequently to the deposition of the oolitic series.

* Mr. Murchison, in his paper on Brora, (Geol. Trans. 2nd Series, vol. ii. p. 304,) mentions a dike of quartz rock as occurring at Kintradwell, on the coast of Sutherland. That gentleman has further informed me, that in company with Professor Sedgwick he noticed similar dikes, both at Ethie and at other places on that coast.

XLII.—*On the Connexion of certain Volcanic Phenomena in South America; and on the Formation of Mountain Chains and Volcanos, as the Effect of the same Power by which Continents are elevated.*

By CHARLES DARWIN, Esq., Sec., G.S., F.R.S.

[Read March 7th, 1838.]

Plate XLIX.

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Introduction.

THE object of the present memoir is to describe the principal phenomena generally accompanying the earthquakes on the west coast of South America; and more especially those which attended the shock that overthrew the city of Concepcion on the morning of the 20th of February, 1835. These phenomena evince, in a remarkable manner, the intimate connexion between the volcanic and elevatory forces; and it will be attempted to deduce from this connexion, certain inferences regarding the slow formation of mountain chains.

Observations on the Earthquake in Chile of Feb. 20th, 1835.

This earthquake has been the subject of several published memoirs: the sixth volume of the Geographical Journal* contains an admirable account of it by Capt. Fitz Roy, R.N., in which many interesting facts are detailed, and the elevation of a large extent of coast is incontestably proved. The Philosophical

* "Sketch of the Surveying Voyage of His Majesty's ships Adventure and Beagle." Vol. vi. Part II. p. 311.

Transactions for 1836, also, contains a memoir on this subject by Mr. Caldcleugh. I must, therefore, refer to these authors, whose statements, as far as I had an opportunity of observing, I can fully corroborate, for a particular description of the earthquake itself, and of the changes of level which accompanied it in the neighbourhood of Concepcion. I will add only a few details, and will then proceed to describe the manner in which the southern volcanos of Chile were affected during the shock.

The island of Juan Fernandez, situated 360 geographical miles N.E. of Concepcion, seems to have been more violently shaken than the opposite shore of the mainland, and at the same time a submarine volcano, which continued in action during the day and part of the following night, burst forth near Bacalao Head, where the depth was afterwards ascertained to be sixty-nine fathoms. This fact possesses a peculiar interest, inasmuch as during the earthquake of 1751, which utterly overthrew Concepcion, this island was likewise affected in a remarkable manner, considering its great distance from the chief seat of disturbance. If any exact record had been kept of that event, many other points of resemblance would probably have been discovered. There is a tradition, that the land was then permanently elevated, and the area affected appears to have been very much the same with that disturbed in Feb. 1835. Molina* also states, that the undulation travelled from the southward; and in this second catastrophe the inhabitants agreed in thinking that it came from S.W., or even more southerly. After an interval of only eighty-four years, it is not at all improbable that the subterranean forces should be directed towards the same identical points.

Being anxious to trace the effects of the earthquake to the south, I wrote, shortly after visiting Concepcion, to Mr. Douglas, a very intelligent man, with whom I had become acquainted in the island of Chiloe; and the answer, which I have received since my return to England, is full of curious information.

He describes the earthquake, which appears to have been felt over the whole area at almost the same minute, (as far as the clocks of the country can be relied on,) as being very violent. He says, that twenty minutes before the great shock a trifling one was felt, a circumstance which I did not hear of in any other part. He was at the time on the island of Caucahue, (one of the many islets on the inland shore of Chiloe) and at the time wrote down the following remarks in his pocket-book: "Felt an earthquake at half-past eleven o'clock, motion horizontal and slow, similar to that of a ship at sea going before a high regular swell, with three to five shocks in a minute, somewhat stronger than the continued motion; direction from N.E. to S.W. Forest trees nearly touched the ground in these directions, but none fell in our vicinity;—pocket compass placed level on the ground, N. point set to lubbers' point; remarked that it vibrated during the violent

* Compendio de la Historia del Reyno de Chile, vol. i. p. 33.

shocks two points to westward and only half a point to eastward; stood at N. when the motion was less violent. Four minutes afterwards, a shock more violent than any of the preceding ones, affecting the compass as before: another violent shock, and then the movements became gradually less distinct, and eight minutes after the first commencement, they entirely ceased."

I have quoted Mr. Douglas's statement with regard to the compass, although it is not clear how any movement could have forced it to oscillate towards one side more than to another. I presume, however, if the needle with its card had not been acted on by the magnetic force, it would have been thrown in the trough (if such an expression may be used,) of the undulation, that is, in a N.W. and S.E. line, and, therefore, that the *recurrence* of this tendency, acting against the polar attraction, caused the unequal oscillations, as described. In my Journal of Researches*, I have endeavoured to show, that the vorticose movement, which in several earthquakes appears to have affected the stones in buildings, possibly may be explained on the same principle, namely, that the stones are so shaken that they arrange themselves according to their forms, in the line of vibration, as the compass would have done, had it not been acted on by the magnetic force. That the movement of the surface was undulatory, is shown by the fact, that at Concepcion the walls which had their extremities directed towards the chief point of disturbance generally remained erect, although much fractured; whilst those extending at right angles to these first lines, were hurled to the ground; for in the latter case we must suppose, that the whole wall was thrown at the same moment out of its perpendicular by coinciding with an undulation.

The fact mentioned by Mr. Douglas of the trees almost touching the ground from the effects of the movement, though very extraordinary, has been noticed by eye-witnesses of earthquakes in other parts of the world†. The circumstance (even supposing it somewhat exaggerated) is the more remarkable, since at Valdivia, which is situated on the coast between this island and the centre of the disturbance at Concepcion, the shock produced no such effects. I was seated in a thick wood there, during the earthquake, and the trees were only slightly shaken.

The range of the Cordillera opposite Chiloe, a narrow island ninety miles in length, is not nearly so lofty as in Central Chile, and a few only of the culminant peaks, which are all active volcanos, exceed 7000 feet in height. Mr. Douglas has given me a detailed account of the effect produced on them by the shock.

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* Journal of Researches during the Voyage of the Beagle, p. 376.

† This is mentioned by Dolomeu as a well-known fact during the Calabrian earthquake of 1783. Lyell's Principles of Geology (5th edition), vol. ii. p. 217.

The volcano of Osorno had been in a state of moderate activity for at least forty-eight hours previously; Minchinmadom in much the same gentle action as for the last thirty years; and the Corcovado had been quiet during the whole previous twelve months. "At the moment of the shock, Osorno threw up a thick column of dark blue smoke, and directly that passed, a large crater was seen forming on the S.S.E. side of the mountain; it boiled up lava, and threw up burning stones to some height, but the smoke soon hid the mountain. When seen again a few days afterwards, it showed very little smoke by day, but by night, the new crater, as well as the old one on its truncated summit, shone with a steady light. This volcano appears to have remained in activity throughout the year. The action of Minchinmadom was similar to that of Osorno: two curling pillars of white smoke had been observed all the morning; but during the shock, numerous small chimneys seemed to be smoking within the great crater, and lava was thrown out of a small one just above the lower verge of the snow. Eight days afterwards this little crater was extinct; but at night five small red flames were seen in a line, equidistant from each other, like those in the streets of a village. By the 1st of March its activity was much diminished; but on the 26th there was a smart earthquake, and at night the five fires were again seen. A fortnight afterwards the tops of fifteen conical hills could be seen within the wall of the great crater, and at night nine steady fires, of which seven were in a line, and two straggling."

At the time of the great shock, the Corcovado showed no signs of activity, nor was it heard in action after the Cordillera were hidden in the clouds. Mr. Douglas, however, states, that when that volcano was visible a week afterwards, the snow was seen to have been melted around the N.W. crater. On Yantales, a lofty mountain south of the Corcovado, three black patches having the appearance of craters were observed above the snow-line; and Mr. Douglas did not recollect having seen them before the earthquake. Bearing in mind, that on many occasions, the melting of the snow on a volcano has been the first indication of a fresh period of activity, and that, as I shall presently show, the eruptions of the Corcovado and Orsono are sometimes co-instantaneous, I think there can be little doubt that these appearances prove the effects of the great convulsion of the 20th of February to have been felt by these, the most southern volcanos in America.

Mr. Douglas states, that on the night of November 11th (ten months after the overthrow of Concepcion), Osorno and Corcovado both burst out in violent action, throwing up stones to a great height, and making much noise. He subsequently heard, that on the same day, Talcahuano, the port of Concepcion, little less than 400 miles distant, was shaken by a severe earthquake. This latter statement has since been confirmed to me by a gentleman, who was at the time resident in Chile. Here, then, we have a repetition of the same connected action, which was displayed in so remarkable a manner on the 20th of February. Mr. Douglas in conclusion adds, that on December the 5th his "attention was arrested by the grandest volcanic spectacle he had ever beheld; the S.S.E. side of Osorno had fallen in, thus uniting the two craters, which appeared like one great river of fire. Enormous quantities of ashes and smoke were erupted during the succeeding fortnight."

It is therefore evident, that the volcanic chain from Osorno to Yantales (a length of nearly 150 miles) was affected not only at the moment of the great shock of February 20, 1835, but remained in very unusual activity during many subsequent months.

Again, on November 7, 1837, two years and three quarters after the overthrow of Concepcion, both Valdivia and San Carlos, the capital of Chiloe, were violently convulsed, even more so, according to M. Gay*, than in 1835, or on any former recorded period; this shock was sufficiently

* Comptes Rendus, 1838. Séance Juin 11.

strong (*bastante recio**) at Talcahuano; and it appears from the evidence of Captain Coste, published in the Comptes Rendus†, that the island of Lemus in the Chonos Archipelago, 200 miles south of San Carlos, was, by this same earthquake, upraised more than eight feet: describing the present state of the island, M. Coste says, "des roches jadis toujours couvertes par la mer, restant aujourd'hui constamment découvertes."

We see, therefore, that, in 1835,—the earthquake of Chiloe,—the activity of the train of neighbouring volcanos,—the elevation of the land around Concepcion,—and the submarine eruption at Juan Fernandez, took place simultaneously, and were parts of *one and the same* great phenomenon. Again in 1837 a large part of the same area was violently affected, whilst a district, 200 miles southward of San Carlos in Chiloe, instead, as in 1835, of 300 northward of it, was permanently upraised. We must therefore believe, that these two elevations of the land, although not simultaneous, were effects of the same motive power intimately connected together.

Although the earthquake of February 1835 was so severe in Chiloe, yet at Calbuco, a village situated on the mainland opposite the northern extremity of the island, it was felt with much diminished violence, and on the neighbouring Cordillera (near Mellipulli) not at all. Some men who had been employed in the mountains splitting fir-planks, when they returned in the evening to Calbuco and were told of the shock, said, that "about the time mentioned, they recollected that they had not been able to strike fair with the axe, and that they had spoilt a board or two, by cutting too deep." This probably is not so fanciful as it at first appears; at least it shows that, if there were any motion, it was of an exceedingly gentle kind. It is a most interesting circumstance thus to find, that the great columns of smoke shot forth from the tall chimneys of the Andes, relieved the trembling ground, which at that moment was convulsed over the whole surrounding country.

Mr. Caldcleugh‡, has stated in his Memoir, that several volcanos in the Cordillera northward of Concepcion were in a state of great activity after the earthquake. It is therefore remarkable that Villarica (near Valdivia), a volcano which is more frequently in eruption than almost any other in the range, although situated in an intermediate position, between those of central Chile and those in front of Chiloe, was not in the least affected. The day was very clear, and although not at the moment of the shock, yet within two hours after it, I attentively watched its truncated summit, but did not perceive the least signs of action. This circumstance probably has an intimate relation with the less force of the earthquake in the same intermediate district. In 1837, however, it suffered similarly with Chiloe. Although Villarica was passed over in 1835, yet in the account of the earthquake of 1822 at Valparaiso, it is said, "at the moment the shock was felt, two volcanos in the neighbourhood of Valdivia (where the earthquake was pretty sharp) burst out suddenly with great noise, illuminated the heavens and the surrounding country for a few seconds, and as sud-

* Voyages of the Adventure and Beagle, vol. ii. p. 418.

† Comptes Rendus, October, 1838, p. 706.

‡ Phil. Transact. for 1836. I likewise was informed by an intelligent person, that he had seen, from the plain near Talca, a volcano in the Cordillera in great activity on the night subsequent to the earthquake.

denly subsided into their quiescent state*." The vents in Central Chile, nearer the chief focus of disturbance, were not at the time of that earthquake affected; but according to the information received by Dr. Gillies† in 1836, from a miner who had resided many years in sight of the volcano of Maypu, its eruptions were very frequent during the four years immediately subsequent to it. Many other instances are on record of earthquakes having passed over certain districts, in the same manner as we see the eruptive force acted with respect to Villarica. Humboldt‡ remarks, that the inhabitants of the Andes, speaking of an intermediary ground, which is not affected by the general motion, say with simplicity, "that it forms a bridge" (*que hace puente*); and he adds, "as if they meant to indicate by this expression, that the undulations were propagated at an immense depth under an inert rock §."

On the identity of the force which elevates Continents with that which causes volcanic outbursts.

It has frequently happened, that during the same convulsion large areas of the globe have been agitated, and strange noises propagated to countries many hundred miles apart‖; but in these cases, it is not possible to form any conjecture over how wide an extent, any actual change has taken place in the subterranean regions. It is different, when we hear from Humboldt, that at the moment when the volcano of Pasto ceased to eject a column of smoke, the city of Riobamba, sixty leagues to the southward, was overwhelmed by an earthquake; for the effect here produced certainly cannot be explained by the mere transmission of a vibration¶. During the Concepcion earthquake,

* Journal of Science, Vol. xvii.

† The Edinburgh Journal of Natural and Geographical Science, August 1830, p. 317.

‡ Humboldt's Personal Narrative, Vol. iv. p. 21. English Translation.

§ Another instance of earthquakes, violently affecting distant regions and passing over the intermediate country, is mentioned in the "True relation of the Earthquake of Lima, 1746." It is there said (p. 192) that the shock was most violent at Lima and Callao, becoming gradually less along the coast, but that at Guancavelica excessive shocks were felt and noises heard. The editor believes, there is no other place called Guancavelica except the famous quicksilver mines of that name, situated 155 miles to the S.E. of Lima. MacClelland (*Report on the Coal Mines of India*, p. 43,) mentions some cases of intermediate places being little shaken during great earthquakes.

‖ As examples of the first case, may be adduced the trembling of the ground on the coast of Chile along a space of more than one thousand miles; and during the Lisbon earthquake in 1755, countries about 3000 miles apart were affected (see Michell on Earthquakes: Phil. Trans. 1760.). With respect to the second case, Humboldt states, that during the eruption at St. Vincent's, subterranean noises were heard on the banks of the Apure, a distance of two hundred and ten leagues. (Person. Narr. Vol. iv. p. 27.) During the eruption of Coseguina in 1835, it is said, that noises were heard at Jamaica, 660 miles distant.

¶ As other instances of the same kind, I may mention the outburst in 1822, of the volcanos near Valdivia at the same moment that Valparaiso, nearly 400 miles distant, was levelled to the ground. Again, in 1746, when Lima was overthrown, three volcanos near Patas and one near Lucanas, the two places being 480 miles apart from each other, burst forth during the same night. (Ulloa's

at one extremity of the area affected, the snow was melted on Yantales and the neighbouring vents renewed their activity; whilst at Juan Fernandez, at the distance of no less than 720 geographical miles from Yantales, an eruption took place beneath the sea; and soon afterwards the volcanos in the Cordillera, 400 miles to the eastward of that island, burst forth in action,—a large extent also of country, intermediate between these extreme points, being permanently upraised. To form a just idea of the scale of this phenomenon, we must suppose, during the same hour, Europe to be shaken from the North Sea to the Mediterranean,—a large tract of the eastern coast of England to be permanently elevated,—a train of volcanos on the northern coast of Holland to burst forth in action,—an eruption to take place at the bottom of the sea, near the northern extremity of Ireland,—and the ancient vents of Auvergne, Cantal, Mont d'Or, and others, so long extinct, each to send up to the sky a dark column of smoke. Moreover, as, in Chile, a large part of the same area was two years afterwards most violently shaken, at the same time that Lemus was upraised, so must we imagine that, subsequently also, in Europe, whilst France, from the English Channel to the central provinces, where the volcanos had been excited into long and fierce action, was desolated by an earthquake, an island in the Mediterranean was permanently elevated;—then should we have the subterranean movements which shook South America on the 20th of February, 1835, and on the 7th of November, 1837, acted in countries with which we are familiar.

When first considering these phenomena, which prove that an actual movement in the subterranean volcanic matter occurred almost at the same instant of time at very distant places, the idea of water splashing up through holes in the ice of a frozen pool, when a person stamps on the surface, came irresistibly before my mind. The inference from it was obvious, namely, that the land in Chile floated on a lake of molten stone, of which the area, as known from the various points in eruption on the day of the earthquake, would be nearly double that of the Black Sea. If this inference be denied, the only alternative is, that channels from the various points of eruption unite in some deep-seated focus, like the arteries of the body in the heart, whence

Voyage, Vol. ii. p. 84.) I allude to these cases more particularly, because that distinguished philosopher, M. Boussingault (*Bulletin de la Soc. Géolog.* Vol. vi. p. 54.), having been much struck with the fact, that the earthquakes which have been most destructive to human life have been unaccompanied by volcanic outbursts, has, I think, generalized the remark too far. The earthquake of Concepcion in 1835 undoubtedly was one of extreme violence, although, from happening in the day, and from *commencing gradually*, it caused but few deaths (probably in the whole province not more than 70); nevertheless we have seen, that it was accompanied by co-instantaneous eruptions from several and very distant points.

an impulse can be transmitted to distant parts of the surface, with nearly equal force. But according to this view, if two separate trains of volcanos in the Andes have any connexion whatever, which seems highly probable from the symmetry of the Cordillera, (and possibly an intimate one, as will presently be discussed,) then the common focus, from which the two main branches are sent off, must be seated at an enormous depth. But all the calculations regarding the depth at which molten rocks must necessarily be met with, if they can be at all trusted *, tend to prove, that the earth's crust is not much more, and perhaps less, than twenty miles in thickness; and if this be so, the crust may, indeed, be well compared with a thin sheet of ice over a frozen pool.

These considerations are, perhaps, of little weight, but we must bear in mind, that the elevation of many hundred square miles of territory near Concepcion is part of the same phenomenon, with that splashing up, if I may so call it, of volcanic matter through the orifices in the Cordillera at the moment of the shock; and as this elevation is only one of a long series, by which the whole coast of Chile and Peru, even for more than a thousand miles, has been upraised several hundred feet within the recent period, (as I endeavoured to show in a paper formerly read to the Society†, and I hope hereafter to prove more fully,) the body of matter added below must have been enormous. When we reflect on this, it is obvious, that the term *channel* cannot be applied to a means of communication extending beneath a large portion of a continent, and from the interior of the globe to the superficial crust ‡. The facts appear to me clearly to indicate some slow, but in its effects great, change in the form of the surface of the fluid on which the land rests.

* M. Parrot, however, (Mémoires de l'Acad. Imp. des Sciences de St. Pétersbourg, Tom. i. 1831. Science. Math. Phys. et Naturelles) altogether denies that the data are sufficient to form any judgment on this subject.

† Proceedings Geol. Soc., Vol. ii. p. 446, Jan. 1837.

‡ Professor Bischoff (Edinburgh New Philosophical Journal, Vol. xxvi. p. 59, 1838.) has even argued that "the immense masses of lava ejected from a single volcano, and the enormous extent in which volcanic actions are felt at the same time, scarcely leave room to doubt that every active volcano is in immediate communication with the whole melted matter in the interior." How incomparably stronger this argument is, if applied to the plutonic as well as volcanic rocks, composing the great masses of the Cordillera! but now that we know, that continental elevations are caused by the very same impulses with those which eject lava and scoriæ through the mouths of volcanos, the argument from the bulk of matter observable in ejected or interjected masses of rock, may be passed over, since the matter added below, when a whole kingdom is permanently elevated, must far exceed that composing either a volcanic hill or the axis of a mountain-chain; and therefore we are so much the more strongly urged to look for its source in "the whole melted matter of the interior," and not in any local receptacle.

In a geological point of view, it is of the highest importance thus to find three great phenomena,—a submarine outburst, a period of renewed activity through many habitual vents, and a permanent elevation of the land,—forming parts of one action, and being the effects of one great cause, modified only by local circumstances. When we consider, that the southern volcanos were in eruption some days before the earthquake, and that one of them, Minchinmadom, has seldom been dormant for the last thirty years, and that they all remained active for many months afterwards, we must conclude that the impulse given to them at that moment, was of the same nature with the force which has kept up their activity during the many ages necessary to accumulate the volcanic matter into great snow-clad cones, and which force still continues to add to their height. If the earthquake or trembling of the ground (which, however, we have seen was less near these volcanos than elsewhere) had acted in no other way, than in merely breaking the crust over the lava within the craters, a few jets of smoke might have been emitted, but it could not have given rise to a prolonged and vigorous period of activity.

But the power which manifested itself in this renewed action, and to which same power, acting at former periods, the entire formation of these several volcanos has evidently been due, was likewise the cause of the permanent elevation of the land;—a power, I may remark, which acts in paroxysmal upheavals like that of Concepcion, and in great volcanic eruptions, in precisely the same manner, for both these phenomena occur only after long intervals of rest, during which the volcano merely casts out, perhaps, a few showers of scoriæ, and the land rises with so slow a movement that it is called insensible;—therefore no theory of the cause of volcanos which is not applicable to continental elevations can be considered as well-grounded. Those who believe that volcanos are caused by the percolation of water to the metallic bases of the earth, or simply to intensely heated rock, must be prepared either to give up this view, or to extend it* to the elevation of such vast continents as that of South America.

* The arguments in favour of the theory, that steam, produced by the percolation of water to the interior of the cooling planet, is the motive power in volcanic action, has been lately strongly put by Prof. Bischoff in his paper in the Edinburgh Journal (Vol. xxvi. p. 25.). That it must be a modifying cause of great importance seems highly probable; but that it is the primary one of continental elevations, I cannot admit. The phenomenon, as it appears to me, is on far too grand a scale to harmonize with such an explanation. Can the *rising* of the whole west coast of South America, and of the whole width, at least of the southern portion of it, be explained by the lateral force exerted during the general shrinking of the earth's crust, modified only by the formation of steam under high pressure, in those parts where water has percolated to the heated interior? Such an explanation surely is inadmissible.

On periods of increased Volcanic Action affecting large Areas.

Humboldt, when describing certain volcanic phenomena in that part of South America which borders the West-Indian sea, seems to consider, that periods of increased activity affect large portions of the surface of the earth. He has drawn up the two following tables*, to which I have added a third, containing the remarkable events that happened during the years 1834 and 1835:

1st. TABLE OF VOLCANIC PHENOMENA.

1796.	November.	The volcano of Pasto began to emit smoke.
1797.	February 4th.	Destruction of Riobamba.
——	September 27th.	Eruption in the West-Indian Islands. Volcano of Guadaloupe.
——	December 14th.	Destruction of Cumana.

2nd TABLE.

1811.	May.	Beginning of the earthquakes in the Island of St. Vincent, which lasted till May 12th.
——	December 16th.	Beginning of the commotions in the Valley of the Mississippi and the Ohio, which lasted till 1813.
——	December.	Earthquake of Caraccas.
1812.	March 26th.	Destruction of Caraccas, earthquakes, which continued till 1813.
——	April 30th.	Eruption of the volcano in St. Vincent's, and on the same day, subterranean noises at Caraccas and on the bank of the Apure.

3rd TABLE.

1834.	January 20th.	Sabiondoy, lat. 1° 15′ N. (near Pasto), dreadful earthquake; eighty persons perished; town of Santiago swallowed up.
——	May 22nd.	Santa Martha, lat. 11° 30′ N.; two-thirds of the town thrown down; in course of a few days, sixty bad shocks.
——	September 7th.	Jamaica,—violent earthquake, town not much damaged.
1835.	January 20th.	Osorno, lat. 40° 31′ S. in eruption.
	Before day-light in the morning.	Aconcagua, lat. 32° 30′ S. in eruption. Coseguina, lat. 13° N. in terrific eruption, continuing in activity during the two ensuing months.
——	February 12th.	Earthquake at sea, very strong off the coast of Guyana.
——	February 20th. $11\frac{1}{2}$ A.M.	Juan Fernandez, lat. 33° 30′ S., submarine eruption. Concepcion, (lat. 36° 40′ S.), and all the neighbouring towns destroyed by an earthquake; the coast permanently elevated. Volcanos along the whole length of the Cordillera of Chile in eruption. N.B. These volcanos remained in activity for some months subsequently, and many earthquakes were felt.
——	November 11th.	Concepcion, severe earthquake; Osorno and Corcovado in violent action.
——	December 5th.	Osorno fell in with a grand explosion.

* Personal Narrative, Vol. iv. p. 36. I have altered some of the dates in these tables, as they did not agree with the text or with the well-known period of the events.

With respect to these tables, it must be observed, that we can never feel sure that the connexion of volcanic phenomena at very distant points is real, until some strongly marked event takes place during the same moment at those points, the intermediate country being likewise affected to a certain degree. In the first two tables, the connexion of the West-Indian vents and the coast of Venezuela may be admitted as almost certain *, nor is the distance very great, being at most only 400 miles. But when, on the one hand, we include Quito, distant from the above area more than 1200 miles, and, on the other, the Valley of the Mississippi, the case is very much more doubtful. The coincidence certainly is very remarkable, both in regard to the commencement and the cessation of the long series of earthquakes which affected South Carolina, the basin of the Mississippi, the Leeward Islands, and Venezuela: yet New Madrid is more than 2000 miles from the latter. A repetition alone of such coincidences can determine how far the increased activity of the subterranean powers, at points so remote, is the effect of some general law, or of accident.

We now come to the third table, with which we are more particularly concerned. I have already described in detail the remarkable volcanic phenomena which happened, in connexion with each other, on the morning of February 20th, 1835, and likewise during the subsequent year.

On January 20th, one month previously, three eruptions, as stated in the table, occurred almost at the same hour in very distant points of the Cordillera. Near midnight on the 19th, the summit of Osorno shone like a great star in the horizon; and this appearance soon increased into a magnificent glare of light, in the midst of which, by the aid of a telescope, great dark bodies were seen to shoot upward and to fall down in endless succession. When I was at Valparaiso some time afterwards, Mr. Byerbache, a resident merchant, informed me, that sailing out of the harbour one night very late, he was awakened by the captain to see the volcano of Aconcagua in activity. As this is a most rare event I recorded the date. Some time afterwards papers arrived from Central America giving an account of one of the most fearful eruptions of modern times †. "On the 19th of January, after twenty-six years' repose, a slight noise, attended with smoke, proceeded from the mountain of Coseguina. On the following morning (the 20th) about half-past six o'clock, a cloud of very unusual size and shape was observed by the inhabitants to rise in the direction of this volcano." Enormous quantities of ashes and pumice were then ejected, and the air was darkened, and the ground convulsed, during the three succeeding days. Nearly two months afterwards the volcano was in action. Mr. Caldcleugh observes, that perhaps the only parallel case on record is the well-known explosion of Sumbawa in 1815.

When I compared the dates of these three events, I was astonished to find that they agreed within less than six hours of each other. Aconcagua is only 480 miles north of Osorno, but Coseguina is about 2700 north of

* Humboldt's Personal Narrative, vol. ii. p. 226., and vol. iv. p. 36.

† Caldcleugh on the volcanic eruption of Coseguina. Philosophical Transactions, 1836, p. 27.

Aconcagua. It may be asked, were these three eruptions, which burst through the same chain of mountains, in any respect connected, or was the coincidence accidental? We cannot be too cautious in guarding against the assumption that phenomena are connected, because they happen at periods bearing some determined relation to each other. If we wished to show that the subterranean forces acted after periods of a century, as has sometimes been believed, we might adduce the case of Lima, violently shaken by an earthquake on the 17th of June, 1578, and again on the very same day in 1678; or the eruptions of Coseguina in the years 1709 and 1809, which are the only two on record previous to that of 1835. Again, we might urge, on such grounds, that the Guatimala convulsions follow, at the interval of one year, those near Pasto; for a district in the neighbourhood of the latter place was overthrown by a violent shock precisely one year before the explosion of Coseguina; both having occurred on the 20th of January. Cosme Bueno imagined that this relation actually did exist between the subterranean movements in Guatimala and Peru, and this case makes one more to the list which I have subjoined* as extracted from Humboldt. With respect to the simultaneous eruptions of Aconcagua and Osorno, there is little difficulty in admitting that they may have been connected, because in this same region, and only a month subsequently, volcanos further apart were affected by the same impulse. There is nevertheless this remarkable difference in the two cases;—the last, or that of February the 20th, was a period of commotion throughout the kingdom of Chile, while the simultaneous eruption of Aconcagua and Osorno appears to have been unaccompanied by any *general* movement in the subterranean regions. This eruption, probably, was the first indication of those great volcanic disturbances which ensued exactly one month afterwards; for it seems to be a very general occurrence in earthquakes, that weak spasms precede the worst convulsions. Thus, in 1822, on the 4th of November, Copiapó (lat. 27° 10′) was visited by a severe shock, which damaged many houses; and was followed the next day by a much more violent earthquake, which nearly destroyed the town, and did considerable

* *Mexico.*	*Peru.*	*Difference of time.*
(Lat. 13° 32′ North.	(Lat. 12° 2′ South.)	
30th of November, 1577.	17th of June, 1578.	Six and a half months subsequent.
4th of March, 1679.	17th of June, 1678.	Eight months in advance.
12th of February, 1689.	10th of October, 1688.	Four months in advance.
27th of September, 1717.	8th of February, 1716.	Seven and a half months in advance.

Humboldt's Personal Narrative, Vol. ii. p. 227. These facts perhaps tend to show that periods of increased volcanic energy are common to remote parts of the continent; but as the order of priority is not constant, I cannot believe any other law is indicated.

injury to that of Coquimbo, in lat. 29° 50′ *. On the 19th of the same month Valparaiso was almost destroyed. Other instances † might be brought forward to show that most earthquakes, though appearing sudden, are in truth parts of a prolonged action, as evinced both by the events which precede and those which follow it.

Although, possibly, we may allow that the eruptions of Aconcagua and Osorno, occurring in the middle of the same night, were connected together, and formed a part of the great subsequent disturbances,—yet what must we conclude respecting their coincidence with Coseguina, so immensely remote? The case is rendered far more extraordinary by two of the three volcanos being generally quiescent. Coseguina, according to Mr. Caldcleugh, burst forth after twenty-six years of repose; and Aconcagua so seldom manifests any signs of activity, that it had even been doubted whether any part of this gigantic mass, with an altitude of more than 23,000 feet, is of volcanic origin. To illustrate the case: if we suppose Stromboli and Vesuvius to be in violent eruption on the same hour of the night, little would be thought of the coincidence; but it would be otherwise if this should happen with Vesuvius and Etna; and our surprise would be greatly increased if we afterwards heard that Hekla, after twenty-six years' repose, had burst forth at the same time with tremendous explosions. Nevertheless, if such a coincidence had occurred in Europe, a country possessing no unity of character, and the two points not being more than 2000 miles apart, it is very doubtful how far the phenomenon would have been worthy of consideration. But the case is different in America, where the volcanic orifices all fall on one great wall or fissure, (for the Andes may be indifferently so called,) and where the immensity of the level area on the eastern side, proves with what wonderful equability the subterranean forces have acted on this portion of the globe. Moreover, when a line of coast more than two thousand geographical miles in length has been elevated (as I hope hereafter to prove) within a period so recent, that, as compared to the countless past ages of which we possess records in the *works* of nature, it may be

* Journal of Science, Vol. xvii.

† Several distinct cases are known in which springs and wells have been affected, their water rendered turbid, and altered in quantity, previously to bad earthquakes. This was observed at Lisbon in 1755; and in New England during two or three days before a shock, "the waters of some wells were rendered muddy and stank intolerably." (Michell, Philosophical Transactions, 1760, p. 44.) Humboldt and others have noticed, that the wells in the neighbourhood of Vesuvius are affected previously to its bad eruptions. These facts appear explicable, on the idea of a slight stretching or movement taking place in the crust, before its tension is overcome, a fissure formed, and, as a consequence, an earthquake or eruption caused. Courrejolles, also, has remarked in his memoir on earthquakes (Journal de Phys., Tom. lxiv. p. 106.), that great earthquakes are almost always preceded by lesser ones.

reckoned as unity; on such a coast it ceases to be improbable, in any excessive degree, that the many impulses which together have produced the one grand effect, should sometimes have been absolutely simultaneous.

It has long been remarked, that the vents throughout the Cordillera may be grouped into several systems. Thus we have already shown, that the extreme southern volcanos are connected with those of Central Chile; and I was informed by an intelligent resident that he had seen Aconcagua and two volcanos northward of it, in great activity together:—we thus have a portion of the Andes 780 geographical miles in length (about the distance from the south of England to Vesuvius) forming one connected system. Ulloa * states, that when Lima was overthrown in 1746, three volcanos near Patas and one near Lucanas burst forth; these places being 480 miles apart from each other. Moreover, Arequipa, to the south, has twice (1582 and 1687) been affected by severe earthquakes simultaneously with Lima. The distance between Arequipa (where there is an active volcano) and Patas is rather more than 600 miles; and this perhaps may form a second system.

Humboldt† says, "it appears probable that the higher part of the kingdom of Quito, and the neighbouring Cordillera, far from being a group of distinct volcanos, constitute a single swollen mass, an enormous volcanic wall stretching from north to south, and the crest of which exhibits a surface of more than six hundred square leagues. Cotapaxi, Tunguragua, Antisana, and Pichincha, are placed in this same vault, on this raised ground." He afterwards shows, from the phenomenon already alluded to, of the cessation of the column of smoke at the moment when Riobamba was overthrown, the connexion of these volcanos with those of Pasto and Popayan. This joint system is rather less than 300 miles in length. Again, to the north at Guatimala, Mexico, and California, we have three groups of volcanos, each system being a few hundred miles apart.

The connexion between the vents in each separate system has been, in some places, plainly shown, and is extremely probable in all; but what relation the different systems bear to each other is more doubtful. I am not aware of any fact on record, similar to the contemporaneous eruption of Osorno and Aconcagua with Coseguina. It must not, however, be overlooked, that such events may have happened every year since the Spanish conquest, without the coincidence having once been detected. Excepting from the concurrence of two accidents, I should never have known of this case. On that same night every vent in the Cordillera might have shown transient signs of activity, and six months afterwards it would have been as impossible to have discovered

* Ulloa's Voyage, English Translation, Vol. ii. p. 84.

† Personal Narrative, Vol. iv. p. 29.

that such had happened, as to have ascertained whether the next day were bright or clouded. There are some active and some nearly extinct craters, in the interval between the Chilian and Peruvian systems, (which is the longest of any, being 900 miles,) but they are situated in countries very thinly peopled, and in some parts entirely desert; and who is there in such cases to record phenomena, which, even if beheld, are thought of little consequence?

Returning to the third table, I feel no doubt that the volcanic phenomena which occurred in S. America sometime previously as well as subsequently to the months of January and February 1835, were far more numerous than the average proportion during an equal length of time. This remark applies to the two tables copied from Humboldt. In looking at the dates of these events, it must be remembered that each date represents only the moment when the crust of the earth has given way beneath the force, which in some cases has already shown its action, and invariably continues to do so during a period, often of considerable length. Under this point of view, the earthquakes of Caraccas and New Madrid, of Coseguina and Concepcion, may be considered as actually contemporaneous.

From these various circumstances, I am strongly inclined to believe, that the subterranean forces manifest their action beneath a large portion of the South American continent, in the same intermittent manner as, in accordance with all observation, they do beneath isolated volcanos,—that is, remaining for a period dormant, and then bursting forth throughout considerable districts with renewed vigour.

Nature of the Earthquakes on the Coasts of South America.

I will now more particularly consider the nature of the earthquakes which occur at irregular intervals on the coast of South America. It cannot be otherwise than difficult to trace their precise origin, but the following considerations, as it appears to me, lead to one conclusion alone—namely, that they are caused by the interjection of liquefied rock between masses of strata. Ulloa, in his travels*, says,

"Experience has sufficiently shown, especially in this country (South America), by the many volcanos in the Cordillera which pass through it, that the bursting of a new burning mountain causes a violent earthquake, so as totally to destroy all the towns within its reach, as happened at the opening of the volcano in the desert of Carguagoazo. This tremulous motion, which we may properly call an earthquake, does not so usually happen in case of a second eruption, when an aperture has been before made, or, at least, the motion it causes in the earth is comparatively but small." †

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* Ulloa's Voyage, Vol. ii. p. 85.

† Michell, in his remarkable paper on Earthquakes in the Philosophical Transactions for 1760,

Although the bursting forth of a *new* vent may invariably be accompanied by an earthquake, the converse is not true; for if it were, at Valparaiso, Concepcion, Lima, Caraccas, and other places, in the *immediate neighbourhood* of the part most violently shaken, an eruption must always have taken place, which, even if we suppose it to have occurred beneath the sea, is improbable in the highest degree. But we may suppose that these earthquakes are owing to some phenomenon analogous to volcanic eruptions. This opinion is much strengthened by the fact, that great earthquakes, like great eruptions, generally recur only after long intervals of repose, and they thus lead us to believe, that the subterranean force is relieved by either in the same manner. This, indeed, is the direct opinion of the inhabitants of the whole west coast of South America, who are firmly convinced of an intimate relation between the suppressed activity of the volcanos in the Andes and the tremblings of the ground. We have, also, seen that, when the island of Chiloe was strongly shaken, some men at work on the flanks of the Cordillera, between the volcanos of Osorno and Minchinmadom, (which both sent up dark columns of smoke, like signals to mark the new period of violence,) were quite unaware of the great convulsion, which then caused the shores of the Pacific to vibrate throughout a space of more than a thousand miles.

There is, however, one difference, although more apparent than real, between earthquakes like that of Concepcion, and those alluded to by Ulloa. In the former, it has almost invariably happened, at least in those on the South American coast, that a vast number of shocks have followed the first great convulsion*, and these, as well as the accompanying subterranean noises, having proceeded from the same quarter with the first shock, are therefore undoubtedly due to the very same cause, only acting with somewhat less intensity. Thus, even in the first twenty-four hours after the earthquake of

(p. 580,) has quoted this same passage in confirmation of his view, that "the eruptions of volcanos which happen at the same time with earthquakes may, with more probability, be ascribed to those earthquakes, than the earthquakes to the eruptions, whenever at least the earthquakes are of considerable extent." The term earthquake is here used to express the cause of the trembling of the ground. Sir James Hall, in his celebrated memoir on "Heat modified by compression," (Edin. Phil. Trans., Vol. vi. p. 166,) distinctly states "that the earthquakes which desolate countries not externally volcanic, indicate the protrusion from below of matter in liquid fusion, penetrating the mass of rocks;" but he does not extend this view, which is the same which I hold, to any comprehensive generalization, or restrict it to any particular class of earthquakes.

* Courrejolles, in his Memoir on Earthquakes, (Journal de Physique, Tom. liv. p. 106,) says, "Les grands tremblemens de terre sont presque toujours précédés et suivis quelque temps avant et après par de petites secousses." Michell (Philosophical Transactions, 1760, p. 10) has given some instances of successive minor shocks, which appeared to travel from the same point, whence the previous more violent ones had come.

1746 at Lima, no less than 200 horrible (I use the language of its historian) shocks were counted. Now in the other case, Ulloa says, that when the orifice of eruption is once formed, the earth becomes nearly tranquil ; yet we well know, that the volcano itself almost invariably continues in great activity for many weeks afterwards. Had Ulloa, however, stood near the crater itself, he would undoubtedly have felt those small tremors, which accompany each fresh explosion, as described by others who have been so circumstanced. The tremors, therefore, seem analogous to the secondary shocks ; and, this being so, the phenomena in the two cases are in every respect closely similar. In a primary volcanic outburst, we know the cause to be the explosion of liquid and aeriform matter, first through solid strata, and afterwards through a nearly open passage ; hence we are led to conclude, that the cause of the simple earthquake, with its secondary shocks, are explosions of a similar nature, which, however, do not open a passage, but rend successively portions of the superincumbent masses.

At Concepcion, where the streets run in two series, at right angles to each other, the walls were affected, as already observed, according to their direction. This was strikingly exemplified in the cathedral, where the great buttresses, built of solid brickwork, were cut off as if by a chisel, and hurled to the ground ; whilst the wall, to support which they had been vainly built, though much shattered, stood erect,—for the latter had its extremity directed towards the point whence the vibration travelled, but the buttresses were in lines parallel to the undulation. Nearly similar circumstances were observed* in 1822 at Valparaiso. At the great earthquake of Caraccas the direction of the vibration was E.N.E. and W.S.W., and some definite direction appears to have been observed in almost every violent earthquake. Now, it may be asked, could a vibration, which had travelled upwards through the earth from a profound depth, be felt on the surface, as if it had come from a given point of the compass, and could it likewise determine the overthrow of walls according to their direction with respect to any such point ? It appears to me clearly not ; but that a vibration to produce such effects must be transmitted from the rending of strata, at a point not very deep below the surface of the earth.

Earthquakes generally affect elongated areas. In the shock of 1837, in Syria, the vibration was felt " on a line 500 miles in length by 90 in breadth†." Humboldt‡ remarks, that earthquakes follow the coast of New Andalusia in the

* See Miers's Travels in Chile, Vol. i. p. 392.

† Proceedings of Geological Society, p. 540. April 5th, 1837.

‡ Personal Narrative, Vol. ii., p. 224.

same manner as they do that of Peru and Chile. Thus, at Valparaiso in 1822, the movement was felt along 880 miles of the shore of the Pacific; and at Concepcion, in 1835, for the greater length of more than 1000 miles; but on no occasion has the shock been transmitted across the Cordillera to a nearly equal distance. In 1835 the rocking of the ground was so gentle at Mendoza, that an old man, one of the inhabitants, (and every one in these countries is possessed with an almost instinctive power of perceiving the slightest tremor,) told me, that for some time he mistook the movement of the ground for a giddiness in his head, and that he called out to his friends that he was going to die. At Concepcion, Valparaiso, Lima, and Acapulco*, the residents believe that the disturbance generally proceeds from the bottom of the neighbouring sea; and thus they explain the unquestionable fact†, that the inland towns are generally much less injured than those near the coast. It does not appear, that the disturbance proceeds from any one point, but from many ranged in a band; otherwise the fact of the linear and unequal extension of earthquakes would be unintelligible. Thus, in 1835, the island of Chiloe, the neighbourhood of Concepcion, and Juan Fernandez, were all violently affected at the same time, and more so than the intermediate districts. In mountainous countries, such as New Andalusia, Peru, and Chile, when earthquakes follow coast lines, they may be said to extend parallel to the littoral chain of mountains.

The last consideration I shall enter on, as indicating the cause of earthquakes, is, that in South America they have sometimes (if not, as I believe, generally‡) been accompanied by elevations of the land; but this, judging from the Lima shock of 1746, does not appear to be a necessary concomitant, at least to a *perceptible* amount. It might at first be thought that, at Concepcion, the uplifting of the ground, which accompanied the first and great shock, would by itself have accounted for the whole phenomenon of the earthquake. The great shock, however, during the few succeeding days, was followed by some hundred minor ones (though of no inconsiderable violence), which seemed to come from the same quarter from which the first had proceeded;

* At Acapulco, Humboldt says, the shocks come from three different quarters, the west, north-west, and south. (Polit. Essay on the Kingdom of New Spain; English Translation, Vol. iv. p. 58.)

† Almost every author, from the time of Molina, makes this observation. See Molina's *Compendio de la Hist. del Reyno de Chile*, Vol. i. p. 32.

‡ My belief is grounded on the fact that, on the same coasts, and within the same period, in which a vast number of earthquakes are recorded, there exist proofs of an elevation of the land; although the rise is not known to have been connected with any particular earthquake.

whilst, on the other hand, the level of the ground certainly was not raised by them; but on the contrary, after an interval of some weeks, it stood rather lower than it did immediately after the great convulsion,—a consequence, perhaps, of the settling down of the shaken ground. In the same manner, in 1822, at Valparaiso, the permanent change of level in the rocks on the coast was observed the morning next after the great shock; though the earth continued to tremble at intervals for many days. In these instances of change of level we have, then, a clear indication of some cause of disturbance, superadded to that which produced the vibrations, and which, it is highly probable, would accompany the simple elevation of the coast in mass.

From these considerations, we may, I think, fairly conclude, with regard to the earthquakes on the west coast of South America,

1st. That the primary shock is caused by a violent rending of the strata, which seems generally to occur at the bottom of the neighbouring sea.

2nd. That this is followed by many minor fractures, which, though extending upwards nearly to the surface, do not (excepting in the comparatively rare case of a submarine eruption) actually reach it.

3rd. That the area thus fissured extends parallel, or approximately so, to the neighbouring coast mountains.

4th. That when the earthquake is accompanied by an elevation of the land in mass, there is some additional cause of disturbance.

And lastly, That an earthquake, or rather the action indicated by it, relieves the subterranean force, in the same manner as an eruption through an ordinary volcano.

Now, what constitutes the axis, where visible, of most great mountain-chains? Is it not a wedge-formed linear mass of rock, which scarcely any geologist disputes was once fluid, and has since cooled under pressure? Must not the interjection of such matter between masses of strata have relieved the subterranean pressure in the same manner, as an ejection of lava and scoriæ through a volcanic orifice? The dislocation having been effected in that portion of the upper crust of the earth, now forming a mountain, must not superficial vibrations, proceeding from a focus not deeply seated, have been propagated over the surrounding country? And, whatever direction these dislocations took, would not an area, elongated in the same line, have been affected by the vibration?

In drawing this parallel, I state my belief, that those earthquakes, with their secondary shocks, which are attended by such phenomena as accompanied the earthquake of Concepcion in 1835, are caused by the rending of great masses of strata, and their interjection by fluid rock;—a process which must have formed one step in a line of elevation.

The inhabitants of Concepcion believed, that the vibrations proceeded from the south-west, in which quarter subterranean noises were likewise frequently heard. It is, therefore, a most interesting circumstance, that the island of Santa Maria, situated 35 miles distant in this direction, was found by Captain Fitz-Roy to have been elevated to nearly three times the height that the coast near Concepcion was upraised. At Tubul, S. by E. of Santa Maria, the land was raised 6 feet; at the southern extremity of the latter island, 8 feet; in its middle, 9 feet; and at its northern extremity, upwards of 10 feet*. These measurements, which were made with extreme care by Captain Fitz-Roy, seem to point out an axis of elevation in the sea off the northern end of Santa Maria.

There is one remark, which I must introduce here. The motion of the earth, on February 20th, 1835, at Valdivia, appeared to me like that of a crust, spread over an undulating fluid; and in my Journal, I have compared the motion to the bending of thin ice, beneath a moving weight. Afterwards, when I became convinced that the crust there does rest upon a sea of molten rock, my first impression regarding the movement was strongly confirmed. Michell long since observed, (Phil. Trans., 1760, p. 8) that "the motion of the earth in earthquakes is partly tremulous and partly propagated by waves, which succeed one another, sometimes at larger and sometimes at smaller distances; and this latter motion is generally propagated much further than the former." This distinction, I believe, is strictly true. Professor Phillips† argues that rocks, although elastic in their parts, are "very imperfectly so in their mass, owing to the numerous divisions which intersect them. Composed of such materials," he says, "the crust of the earth does not, and in fact hardly can, *vibrate*, in the ordinary sense of this term; the motion observed is more similar to the undulation of a flexible lamina over an agitated liquid." The result arrived at by this reasoning thus coincides with mine, drawn from the impression on my senses; and it, at first, appears to explain, in a very satisfactory manner, the propagation to greater distances of the long and gentle undulations than of the vibrations, by the transmission of the former in the subterranean fluid, and of the latter in the crust of the earth. With respect, however, to the supposed want of elasticity in the crust of the earth, taken in mass, I cannot agree with Professor Phillips. Michell, (Phil. Trans., 1760, p. 35,) when he adduces the fact of the great vibration, or rather oscillation, during gales of wind, of steeples, and even towers†, which may be said to be composed of a vast number of strata of different densities, and which are frequently traversed by fissures or faults, leaves

* Geographical Journal, Vol. vi. p. 327.

† Lardner's Encyclopædia, Geol., Vol. ii. p. 209.

scarcely any doubt on the mind that a similar and much greater vibration might be transmitted from the depths of the earth, where the parts must be pressed together with incomparably greater force than in any building. Plausible as is the foregoing explanation of the two kinds of movements, I do not believe it to be the correct one; for if an undulation be ever produced in the subterranean fluid expanse, we can hardly conceive a more powerful cause of it, than the upward rush of a great body of molten rock and aëriform matter from the lowest abyss of a volcano: but we know that eruptions on an enormous scale have happened through old vents, even in areas subject to far-extended and undulating earthquakes, without such movements having been produced. From this consideration, and from the fact that the force of earthquakes appears to have a definite relation to the thickness of crust ruptured, as we may conclude from the great difference in the effects caused by an eruption through an old, and one through a new orifice, I do not conceive we are justified in admitting the hypothesis of an undulating fluid. The two kinds of movements may, possibly, be explained, by considering that when the crust yields to the tension, caused by its gradual elevation, there is a jar at the moment of rupture, and a greater movement may be produced by the tilting up of the edges of the strata and by the passage of the fluid rock between them. In breaking a long bar of steel, would not a jar be caused by the fracture, as well as a vibration of the two ends when separate?

Mr. Hopkins*, in his Researches on Physical Geology, has demonstrated, that when an elongated area is elevated by a force acting equally beneath all parts, if the strata yield, fissures must be formed parallel to its longer axis, and other minor ones transverse to it. Knowing then with certainty, that the coast of Chile, near Concepcion, was elevated on the 20th of February, and likewise that the area affected by the earthquake was elongated;—bearing also in mind, that several of these elevations have occurred, as attested both historically and by the extensive beds of recent species of shells, at the altitude of some hundred feet, we are absolutely compelled to believe, that the area (without we assume that the strata possessed extraordinary powers of extension) was at that time fissured in lines, the principal of which were parallel to its longer axis. If, however, the elevatory force acted unequally in different parts, as was the case in Chile, we can understand, from the admirable generalization of the same author, that separate fissures might be formed, which would produce at the same instant, in distant places, separate shocks, perhaps of different intensities. Hence we need not suppose, that the shocks felt more strongly at Juan Fernandez, Concepcion, and Chiloe, than at intermediate points, pro-

* Transactions of the Cambridge Philosophical Society, Vol. vi. Part I.

ceeded from any one focus, but that they were generated in each separate district,—the vibrations probably having, in each case, different directions *. This explanation is, I think, far more satisfactory than that offered by Humboldt, of the supposed inertness of an intermediary mass of rock, in transmitting to the surface vibrations from a deeply-seated focus.

On different kinds of Earthquakes; and conclusions regarding those which accompany Elevatory Movements.

I confine the foregoing observations to the earthquakes on the coast of South America, or to similar ones, which seem generally to have been accompanied by elevation of the land. But, as we know that subsidence has gone on in other quarters of the world, fissures must there have been formed, and therefore earthquakes. I think, it would be highly advantageous to geology, if the author who has followed out the effects of an elevatory force, would consider those produced by the failure of support in the arched surface of the globe. The earthquakes of Calabria, and perhaps of Syria, and of some other countries, have a very different character from those on the American coast. When Molina, the historian of Chile was in Italy, he was much struck with this difference; he says†, in Chile even the smaller shocks extend over the whole kingdom, and are propagated horizontally, whilst those which he felt at Bologna, were of small extension, but instantaneous, and commonly explosive.

I will add, that in the accounts collected by Mr. Lyell‡ of the earthquakes of Calabria, Lisbon, and some other places, portions of the surface are described as having been absolutely engulphed, and seen no more: but this does not appear to have happened in any of the earthquakes on the west coast of South America. If the fluid matter, on which I suppose the crust to rest, should gradually sink instead of rising, there would be a tendency to leave hollows, and therefore a suction exerted downwards; or hollows would be actually left, into which the unsupported masses might be precipitated with the violence of an explosion. Such earthquakes, we may conclude, from what has been shown in the foregoing part of this paper, would seldom be accompanied by eruptions, and never, probably, by *periods* of renewed volcanic

* At Concepcion the line of vibration appears to have been N.W. and S.E., coming from S.W. At Mocha, (an island between Concepcion and Valdivia), from the manner in which water oscillated in the bottom of a boat drawn up on shore, the vibration must have been N. and S. coming from either E. or W. For the facts alluded to, see Capt. FitzRoy's account of the Voyages of the Adventure and Beagle, volume ii. p. 414.

† Compendio de la Historia del Reyno de Chile, Vol. i. p. 36.

‡ Principles of Geology, 5th edit. Vol. ii. Book ii. Chap. xiv.

energy. According to M. Boussingault*, those earthquakes in South America which have been most destructive to human life, that is, which have been most sudden and violent, have not coincided with volcanic eruptions. He adduces several instances, including the shocks felt at Caraccas in 1812; but, according to Humboldt†, the connexion between the subterranean disturbances at that place and the West Indian vents can hardly be doubted. M. Boussingault's remark, indeed, although perhaps generally true, should be taken with some reserve; for had the earthquake of Concepcion happened at night, thousands of persons must inevitably have perished.

In a line of fracture, produced by subsidence, the distortion and overthrow of the strata would probably be even greater than in one of elevation, from the circumstance, that as soon as the weight of the mass overcame its cohesion, and it began to sink, there would be no counterbalancing power, like gravity during elevation, to check the movement, excepting, indeed, the lateral pressure of the masses together, and this would only add to the disturbance. There would be, in this case, no axis of injected plutonic rock, or at least not one protuberant above the general surface; and thus we may explain the extreme disturbance in the strata of countries which are only hilly, like parts of Great Britain; and the occurrence there of such axes of elevation, as they are generally called, but which probably, in most cases, would be more appropriately termed axes of subsidence.

If the theory which I have given of the cause of the earthquakes on the west coast of South America be true, we might naturally expect on the same principle to find proofs of successive formation in the many parallel ridges, of which the Cordillera is composed. In the parts of Central Chile which I examined, this is true, even with regard to the two main lines; of which one is partly formed of inclined beds of conglomerate, consisting of pebbles derived from the rocks of the other. I have also evidence, but of a less satisfactory kind, that some of the exterior lines of mountains are altogether of subsequent date to the more central ridges. Moreover, in all parts of the Cordillera, there are proofs of an equable elevation *in mass* to a very great altitude. I was so much struck with this latter fact, connected with what I imagined must have taken place during the Concepcion earthquake, that I came to nearly the same conclusion, which Mr. Hopkins has demonstrated by his mathematical researches, namely, that mountain-chains are only subsidiary and attendant phenomena on continental elevations. If this be so, and few, after having read Mr. Hopkins's memoir, will dispute it; then, as it is certain continental elevations have certainly taken place on a great scale within the

* Bulletin de la Soc. Geol., Vol. vi. p. 54.

† Personal Narrative, Vol. ii. p. 226, and Vol. iv. p. 6, English Translation.

recent period, so, as certainly, must masses on the lines of fracture have been unequally lifted up and let down,—that is, some steps in the formation of a mountain-chain have been produced.

I may here ask, when Mr. Hopkins* says, he "can in no way conceive the successive formation of parallel fissures, without hypotheses respecting the mode of action of the elevatory force, which are infinitely too arbitrary to be admitted for an instant," has he considered the effects of long intervals of rest, during which the injected rock might become solid? Would not the crust in such case yield more readily on either flank, as I believe it must have done in the Cordillera, than on the line of an axis composed of solidified rocks, such as granite or porphyry? An extremely slow elevation of the land, with long intervals of rest, being the only kind of movement of which we have any knowledge, the slow cooling of that portion of the liquefied rock which is propelled into the upper parts of the crust, cannot be considered an arbitrary assumption.

From the facts stated in this paper, we may safely conclude, that volcanic action, even on a *very grand scale*, as in the Andes, is only one effect of the power which elevates continents, at the slow rate at which the South American coast is now rising. In looking back to the past history of the world, we learn from Mr. Lyell†, that there have been volcanic eruptions during every epoch, from that of the Cambrian formations to the present day. The ancient eruptions seem to have been accompanied by all the circumstances which attend modern ones; nor is there any evidence, as remarked by the same author, that the quantity of matter ejected, in the greater number of ancient cases, was excessive. Therefore, we must conclude that continental elevations, one of the effects of the same motive power which keeps the volcano in action, has ordinarily gone on, since those ancient days, at the same slow rate as at present, and, consequently, as above inferred, the step-like formation of mountain-chains. It may, therefore, be questioned, whether we are justified in admitting the hypothesis of a paroxysmal elevation of any mountain-chain, without distinct proofs in each particular case, that a series of impulses, like those, which now acting frequently on the same lines, rend the earth's crust,

* Abstract of a Memoir on Physical Geology, by W. Hopkins, Esq., M.A., p. 31.

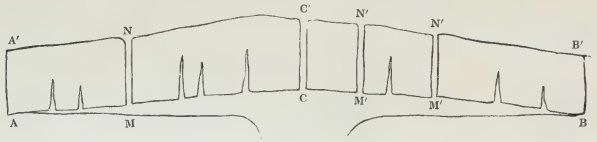
† Elements of Geology. In the 24th chapter, Mr. Lyell has collected instances of volcanic eruptions in each of the great epochs of the geological history of Europe. The argument, which follows in the text, is the same with that advanced by this author in the Principles of Geology, (Book I. Chap. v.) but Mr. Lyell more particularly applies it to the earthquakes and convulsions, "caused by subterranean movements, which seem to be merely another portion of the volcanic phenomena."

and elevate unequally portions of it, could not have effected the observed effects. It is, however, a subordinate question, whether there exist proofs of paroxysmal violence in some mountain-chains; the important fact which appears to me proved, is, that there is a power now in action, and which has been in action with the same average intensity (volcanic eruptions being the index) since the remotest periods, not only sufficient to produce, but which almost inevitably must have produced, unequal elevation on the lines of fracture.

Theoretical Considerations on the slow Elevation of Mountain-Chains.

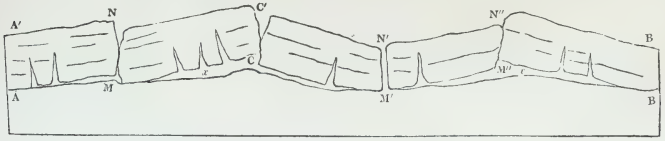
The conclusion that mountain-chains are formed by a long succession of small movements, may, as it appears to me, be rendered also probable by simple theoretical reasoning. Mr. Hopkins has demonstrated, that the first effect of equably elevating a *longitudinal* portion of the crust of the earth, is to form fissures, parallel to the longer axis (with others transverse to them, which may here be neglected) of the kinds represented in the accompanying diagram (No. 1.), copied from that published in the Cambridge Philosophical

No. 1.



Transactions. But he further shows, that the square masses, now disjointed, will,—from the extreme improbability of the force uplifting them, when separate, equably, or from their settling down afterwards,—assume some such position as that given in Diagram No. 2. In the Cordillera, which may be taken

No. 2.



as a good example of the structure of a great mountain-chain, the strata in the central parts are inclined more commonly at an angle above 45°, than beneath it; and very often they are absolutely vertical. The axis of the lines of dislocation is formed of syenitic and porphyritic masses, which, from the

number of dikes branching from them, must have been fluid when propelled against the lower strata*. If then we suppose Diagram 2 to represent the section of the Cordillera before its final elevation, I may ask, how is it possible, that some of the masses of strata should be placed vertical, and others absolutely overturned, by the action of the *fluid* rock, without the very bowels of the earth gushing out? Should we not have one enormous deluge of volcanic matter, instead of wedge-formed, injected masses of solid crystalline rock? On the other hand, if we suppose the loftiest chain of mountains to be formed by a succession of shocks similar to those of Concepcion,—a few stronger and many slighter ones, separated from each other by long intervals of time,—then we may believe, that the formation of a fissure through the whole thickness of the crust would be the effect of many efforts on the same line, and that during the intervals, the rock first injected would become cooled. When, therefore, the tension (which, according to Mr. Hopkins, acts on the lower surface first†) caused the upper part to crack, the fissures, if on the same line, would meet the consolidated extremity of a dike, instead of the fluid mass below. In those cases, however, where the fissure happened to traverse at once the entire crust, a volcano would be formed, such as that near Juan Fernandez during the Concepcion earthquake. On the same principle, after the masses of strata had been very gradually lifted into the position represented in Diagram 2, the rock beneath the anticlinal axes, from having been propelled beyond its former subterranean isothermal line, would be cooled, and, if sufficient time were allowed, it would be consolidated. In this manner the strata, each new fracture being firmly cemented by the cooling of the injected rock, might be overturned into any possible position, and yet, from a gradually thickening crust being formed over the fluid mass, on which the whole is believed to rest, the earth would be protected from a deluge of lava. If this reasoning be sound, we may deduce this remarkable conclusion, that in a mountain-chain, having an axis of plutonic rock, which was propelled upwards in a fluid state, where the strata betray the effects of

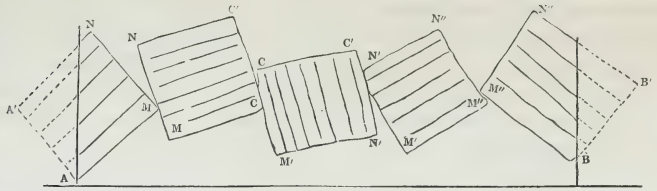
* According to M. Boussingault (Bulletin de la Soc. Geol., Tom. vi. p. 55), this is not the case in the Cordillera of the Equatorial regions. He states that trachyte there forms the base of the mountains, and that it has been protruded in a consolidated form. But can the *deep-seated* axis of a gigantic mountain-chain be composed of trachyte,—a rock essentially *volcanic*? If we could penetrate to greater depths, it cannot be doubted we should find the trachyte graduating into some plutonic rock; and one may be allowed to suspect that its junction with the superincumbent strata would present very different appearances from that of the trachyte;—the trachyte, indeed, we may well imagine to be the crust of such plutonic rocks cooled under little pressure, and forced upwards on the surface of the molten mass, in a solid form.

† Cambridge Philosophical Transactions, Vol. vi. pp. 43–45.

the most violent action, although it be on a gigantic scale, there we have the best evidence of an almost infinite series of small movements*.

I will enter on only one other consideration connected with this subject. From having in my mind the proportional thickness of the strata, usually given in sections in geological works, I felt much surprise, when I crossed the Cordillera, and found highly-tilted anticlinal lines succeeding one another at short distances, that the rock composing the axis was not to be met with, except in patches in the valleys. If we suppose parts of the strata in Diagram 2 to be placed vertically, the rock of the axis would necessarily be exposed in wide spaces; but here, I believe, is the source of error,—geologists have not always sufficiently considered the thickness of the mass upturned, in relation to the distance of the parallel anticlinal lines one from another. In the Cordillera, in a width of about sixty miles, there are eight or more anticlinal lines; and thus the centres of the troughs and of the ridges are about four miles apart. Now, if we suppose the upturned crust to be only four miles thick, (which is somewhat more than can actually be seen,) the strata, when placed vertically, will occupy as great an horizontal extension as they did before they were disturbed. In Diagram 3, which I beg it may be understood is given merely to illustrate this *one* point, I have taken portions of strata of the same exact length as those in Diagram 2; but I have increased their

No. 3.



thickness, so that it equals the distance of the anticlinal lines from each other; —we shall now see that not only the whole axis is covered, but that the masses cannot be forced into their former horizontal limits. I have not, however, allowed for the immense abrasion which, under such circumstances, the lower

* Humboldt has insisted on the fact, that in double chains of mountains, such as form large portions of the Andes, the lofty parts of one line correspond with the lower parts of the other. Such symmetry of structure is hardly conceivable on the idea of mountains having been formed by paroxysmal violence; but if we consider the whole range as the effect of a widely-extended elevation, prolonged during many ages, it is easy to understand, that if one line be weak, and consequently be subjected, for a long time, to disturbance from the subterranean force, it is probable that during so much the less time will the parallel and approximate one be affected.

angles would suffer, nor for the denudation and rounding of the upper ones. This supposed crushing together of such gigantic fragments will, perhaps, explain the utter confusion, which must be familiar to every geologist who has examined any great mountain-chain*. I must here add, that according to these views, which I believe are correct, the theoretical part of the foregoing argument, namely the difficulty of confining during any paroxysmal movement the fluid matter within the crust, is weakened; yet I believe the principle holds good, for, in order to break up and throw over portions of *very thick* crust, as in Diagram 3, there must have been great horizontal extension, and this, if sudden, would have caused as many continuous outbursts of volcanic matter, as there now are axes of solid rock. Moreover, when we consider, first, that the fragments must have stood for one instant separate from each other, and, secondly, that the force necessary to turn over and crush together at one effort these immense masses, must have been in proportion enormously great to that required merely to lift them,—it cannot, I think, be doubted for a moment, that if the force had acted *suddenly*, these portions of the earth's crust would have been absolutely blown off, like fragments of rock by gunpowder; but this has not happened, and, therefore, the force did not act suddenly†.

If we grant that the earthquake of Concepcion on the 20th of February marked one step in the elevation of a mountain-chain; then, as during the twelve succeeding days there were counted upwards of three hundred shocks, which proceeded from the same quarter with the great shock, so the fluid stone

* In the Cordillera, the axis of plutonic rock is less exposed in the principal, than in the subordinate lines; some strongly marked exceptions, however, occur. In the former, also, the strata are most inclined. As, according to the views here advocated, the formation of a mountain-chain is due to innumerable impulses, the highest part must generally have felt the greatest number of impulses, and therefore its stratification would generally be most disturbed. And if a great part of the disturbance be due to the lateral force resulting from the compression of the great *thick* portions of the earth's crust, then the central lines, or those which have several ridges on both sides of them, would be most crushed together, and consequently the strata would be most closely packed over them. I can understand on no other principle, the circumstance of the rock of the axis being visible not on the loftiest, but on the secondary lines of a mountain-range, which very frequently occurs.

† Mr. Hopkins moreover argues, (Abstract of a Memoir on Physical Geology, p. 15,) that if the elevatory force had the character of an *impulsive* action, it "would produce the most irregular phenomena, and such as would be altogether without the sphere of calculation. I exclude, therefore, the hypothesis of this kind of action, not as involving in itself any manifest improbability, but as inconsistent with the existence of distinct approximations to general laws in the resulting phenomena." In other parts the author shows that such approximations do exist in nature.—See also Phil. Mag. 1836, Vol. viii. p. 234.

must have been pumped into the axis by as many separate strokes; nor did the process cease for many subsequent months*. In the central ridges of the Cordillera, there are masses of compact unstratified rocks, half again as lofty as Etna, and I believe, from the reasoning above given, that they were formed by steps nearly as slow as those indicated by the innumerable layers of volcanic matter accumulated on the flanks of the Sicilian mountain. In the volcano, that is, a mountain which has been ruptured in its incipient state, the fluid stone being brought to the surface is rapidly cooled, and hence successive layers are formed; but in the axis of plutonic formation (or subterranean volcano, if it may be so called), the injected matter, not being rapidly cooled, is blended into one huge conical pile. This whole view is nothing more than an application of Hutton's doctrine of the repetition of small causes to produce great effects; and which Mr. Lyell has already brought distinctly to bear on this particular subject.

The action of the elevatory force, as known by beds of littoral shells, successive lines of aqueous erosion on cliffs of solid rock, and terraces rising one above another, seems everywhere to have been prolonged, although intermittently: in the volcano, the structure of the mountain, as well as all history, bespeaks the same fact with respect to the eruptive force. During the Concepcion earthquake, we have seen that these powers, so analogous in their action, were absolutely parts of one common phenomenon. Bearing in mind Mr. Hopkins's demonstration, if there be considerable elevation, there must be fissures, and, if fissures, almost certainly unequal upheaval, or subsequent sinking down,—the argument may be finally thus put:—mountain-chains are the effects of continental elevations; continental elevations and the eruptive force of volcanos are due to one great motive power, now in progressive action; therefore the formation of mountain-chains is likewise in progress, and at a rate which may be judged of by either phenomenon, but most nearly by the growth of volcanos.

Concluding Remarks.

With these views, if we look at a map of America, and observe the continuity of the great chain of the Andes, and its lesser parallel ones, in which from lat. 55° 40′ South to 60° North, a space of little less than 7000 miles, the volcanic forces either now are, or recently have been, in action,—and likewise the symmetry of the whole,—we shall be deeply impressed with

* In an extract from a letter, dated Concepcion, May 6th, that is seventy-six days after the great earthquake, there is this passage:—"It is only since a few days, that a day has passed without a shock, and even yesterday we had one."

the grandeur of the one motive power, which, causing the elevation of the continent, has produced, as secondary effects, mountain-chains and volcanos. The same reasons which led me to the conviction, that the train of connected volcanos in Chile and the recently uplifted coast, together more than 800 geographical miles in length, rested on a sheet of fluid matter, are applicable with nearly equal force to the areas beneath the other trains. We see that these areas are connected by one uniform chain of mountains, from many distant points of which fluid rock is yearly ejected; and as there are proofs that nearly the whole west coast of South America has been elevated within a period geologically modern, and that this movement, in some parts at least, has extended across the continent,—keeping, also, in mind the probability, that during periods of increased subterranean action, such as those indicated in the foregoing tables, the whole western part of the continent has been almost simultaneously affected, it appears to me, that there is little hazard in assuming, that this large portion of the earth's crust floats in a like manner on a sea of molten rock. Moreover,—when we think of the increasing temperature of the strata, as we penetrate downwards in all parts of the world, and of the certainty that every portion of the surface rests on rocks which have once been liquefied;—when we consider the multitude of points from which fluid rock is annually emitted, and the still greater number of points from which it has been emitted during the few last geological periods inclusive, which, as far as regards the cooling of the rock in the lowest abysses, may probably be considered as one, from the extreme slowness with which heat can escape from such depths;—when we reflect how many and wide areas in all parts of the world are certainly known, some to have been rising and others sinking during the recent æra, even to the present day, and do not forget the intimate connexion which has been shown to exist between these movements and the propulsion of liquified rock to the surface in the volcano;—we are urged to include the entire globe in the foregoing hypothesis.

To the belief in these large seas of molten rock, not to speak of an entire concentric layer so constituted, it has been objected, that if its fluidity be tolerably perfect, (which there is good reason to think is the case from what we see of the junction of the plutonic with the metamorphic formations,) the lava ought to stand (supposing a comparative examination possible) at nearly equal heights, within neighbouring volcanic orifices. To this I may answer, if it be permitted me to assume that the subsiding as well as the rising areas rest on a fluid surface, that whatever the power is which causes one to rise and another to sink, acts with unequal force (greatly modified, also, by unequal resistance) in different parts of even a very limited area. The main strength of the earth-

quake of February 20th, 1835, passed over Valdivia, but affected the districts north and south of it; and it appears that this town, until November 1837, had been less injured by the innumerable shocks which devastated Chile than any other; yet the subterranean abysses directly beneath it are in connexion (as shown by the action of Villarica in 1822) with the district to the North, which has been so often convulsed; and in November 1837, at the same time that an island far southward was upraised eight feet, it was shaken by an earthquake so violent that it escaped utter ruin only from the houses being built of wood. The comparative freedom from disturbance of Valdivia on the 20th of February, cannot be attributed to the action of Villarica, for we have seen that this volcano was quiet; nor indeed is there any reason why such an effect should be attributed to its action, since the eruptions of Osorno and Minchinmadom did not save the northern parts of Chiloe, though they occupy the same relative situation with regard to them, which Valdivia does to Villarica. Shall we then say, that Valdivia escaped so long the subterranean disturbances, some of which affected simultaneously regions north and south of it, solely on account of the greater strength of the crust in that part? This appears to me a cause quite inadequate; and the direct supposition is better, that as within the same period one part of the continent has been elevated more than another, so the lava has been propelled by the action of this force more powerfully towards some, than towards others, of the volcanic orifices which penetrate it.

The secular shrinking of the earth's crust has been considered by many geologists a sufficient cause to account for the primary motive power of these subterranean disturbances; but how it can explain the slow *elevation*, not only of linear spaces, but of great continents, I cannot understand. With the same view, some highly important speculations have recently been advanced,—such as changes of pressure on the internal fluid mass, from the deposition of fresh sedimentary beds, and even the attraction of the planetary bodies on a sphere not solid throughout; but we can see that there must be many agents, modifying all such primary powers; and the furthest generalization, which the consideration of the volcanic phenomena described in this paper appears to lead to, is, that the configuration of the fluid surface of the earth's nucleus is subject to some change,—its cause completely unknown,—its action slow, intermittent, but irresistible.

XLIII.—*On the Physical Structure of Devonshire, and on the Subdivisions and Geological Relations of its older stratified Deposits, &c.*

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Woodwardian Professor of Geology in the University of Cambridge;

And RODERICK IMPEY MURCHISON, Esq., F.R.S., V.P.G.S.

[Read June 14th, 1837.]

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PART I.

INTRODUCTION.

IN a communication made to the British Association during its meeting at Bristol (1836), we first pointed out (by help of a section extending from the north coast of Devon to Dartmoor) the true geological position of the great culmiferous deposits, which occupy so large a portion of that county. In this paper our object is more extensive; for we not only attempt to describe the

order of the successive formations north of Dartmoor, but also, as far as we are able, to bring them into comparison with the formations which are expanded from the south side of the Dartmoor granite to Start Point, and to the other headlands of the south coast of Devon. We believe that our present attempt is almost entirely new; for though some portions of the county have been described in considerable detail, yet the several parts have not been brought into any distinct comparison with one another; and in all the published geological maps, the greater part of the slate-rocks have been represented under one colour, without an attempt either to separate them into distinct formations or to mark their succession*. Still less has any attempt been made to bring them into a strict geological comparison with the other mountain groups of England and Wales. Our present object is to exhibit a synopsis of the evidence by which the successive formations are determined. But in future and longer communications, we hope to lay more ample details before the Society, and to describe a large number of organic remains, by help of which, the successive deposits may be referred still more precisely to their true place in the series of British formations, inferior to the carboniferous groups. We are aware of the great difficulty of our task, and if we can succeed in taking only the first step towards its accomplishment, our labours will be well rewarded†.

Chap. I.—*Five Geographical Regions of Devonshire.*

(See Map, Pl. L.)

Considered geologically, and under the most general point of view, Devonshire may be divided into at least five distinct geographical regions.

* Mr. Greenough represents the slate-rocks under two colours. But the separation is founded on mineral characters and not on age; for even a portion of the culm series, altered near the granite, is represented of the same colour with the oldest slate-rocks of Cornwall.

Rev. J. J. Conybeare made also a separation of the Cornish and Devonian slates into two groups, partly on the same principle, and certainly with no reference to any ascertained order of superposition. His papers, which he did not live to finish, contain some excellent details. Mr. H. T. De la Beche, in the first edition of the Ordnance Map of Devon, (which had been published sometime before our examination of the county,) included (with the exception of the district of Start Point) the whole slate series and the culm-measures under one colour, not attempting any separation of them.

† The details alluded to in the *Introduction* are now given in Part II. of this paper. The whole text of Part I. is printed (with the exception of verbal corrections and an expansion of one or two mere mineral descriptions,) from the communication made by the authors in June 1837. A *few sentences* at the end of it, in which the oldest rocks of North and South Devon were placed provisionally in the Upper Cambrian and Lower Silurian system, are now omitted, as the authors, after a more mature examination of the fossils, are convinced that, so far, their first conclusions were erroneous. This omission will be alluded to again in the Introduction to Part II. (June 1839.)

1st. One of them extends through the most eastern portions of the county; and is almost exclusively made up of deposits belonging to the formations of new red sandstone and green sand*. To describe any portion of this region forms no part of our present object. But we may just observe, that the new red sandstone is expanded through a part of it, in a series of rich valleys and low well-wooded plains, which are prolonged northward to the coast of Somersetshire; while the green sand forms, almost without exception, the summits of high barren tabular hills. These two characters, and the horizontal position of the strata, at once distinguish this *first region* from all the others.

2nd. The *second region* occupies all the most northern parts of the county; being bounded to the east by the Vale of Taunton, and the plains of new red sandstone above-mentioned, extending thence to the coast of Somersetshire; to the north and west by the sea-coast; and to the south, by a line commencing at Fremington Pill on the south side of the Barnstaple river, thence ranging through a low undulating region in a direction about east and by south, (passing about two miles north of South Molton, Bampton, and Holcombe Rogus,) so as finally to terminate in the above-mentioned plain of the new red sandstone.

Along a considerable part of the north coast runs an irregular chain of rugged hills, intersected by some valleys of exquisite beauty, and forming a noble series of perpendicular cliffs and bluff headlands. One or two of the highest points of this coast chain, between Minehead and Combe Martin, reach an elevation of about twelve hundred feet.

In the interior of this region is a succession of still loftier elevations, (Dunkery Beacon attaining the height of more than 1600 feet,) which in some places put on the character of a mountain chain. But what we chiefly wish to observe is, that these interior ridges form a regular crest or water-shed, which (with a few inconsiderable deviations) ranges as far as the meridian of Ilfracombe, in a direction almost exactly parallel to the southern boundary above indicated. From many parts of this water-shed, the country descends towards the south by a succession of long sweeping inclined planes; giving to the country an external character which is remarkably contrasted with the features of the great undulating region that lies expanded further towards the south.

3rd. The *third region* commences immediately on the southern limit of the

* The tertiary basin of Bovey Tracey, chiefly occupying a depression among the older strata, may perhaps seem an exception to these remarks. It is, however, too inconsiderable in extent to be noticed in a general sketch like the present.

second, and occupies a great superficial area; extending in length, from the plains of the new red sandstone, in the drainage of the Ex, to the western cliffs of the county; and in breadth, from the southern limits of the second region (as above described) to the northern flanks of Dartmoor and the hilly country S.W. of Launceston. The northern limit of this great area is therefore sufficiently well-defined for our present purpose. Its southern limits are not so easily described; the strike of the beds having (through a considerable extent) been interrupted and distorted by the protrusion of the Dartmoor granite; we may, however, state in a few words,—that the western extremity of the boundary-line runs into the sea immediately to the south of Boss Castle harbour, in the county of Cornwall, and ranging thence in a direction bearing a little to the south of east, it passes about a mile and a half to the south of Launceston, crosses the Tamer still further to the south, and just skirting the great mining-field north of Tavistock, abuts against the granite of Dartmoor. From this junction, the boundary-line is defined by the northern and north-eastern edge of the granite as far as the Bovey basin. The remainder of the line, from the Bovey basin, round the north end of Haldon, to the drainage of the Ex, is too complicated to admit of a clear description without the help of a good map. But the deposits of the third region are not confined to the limits here indicated, as they form an outlying mass resting on the limestone to the south of Newton Bushel*.

The whole of the great area inclosed between these boundaries is occupied by rocks of one formation, the greatest part of which are thrown into violent undulations, exhibiting an incredible number of anticlinal and synclinal lines, generally running, with the strike of the beds, nearly east and west. These contortions are not merely seen in the cliffs and quarries, but they have produced an impress on the whole surface of the region; which, without containing any hills of great elevation, is thrown into an almost continuous succession of undulations, resembling the waves of a tumultuous sea. These characters, however, disappear near the northern and southern boundaries of the region, where the beds generally acquire a more steady dip, and, as we shall hereafter show, form the bottom of a great trough, so as to repose on all the other stra-

* The whole south boundary of the culm-measures was re-examined, by one of the authors, in 1836, after the Bristol meeting above mentioned. To the N.E. of the Newton limestone (and beyond the limits of this outlier) he found the older fossiliferous slates stretching towards Dartmoor. Hence he concluded, that the culm-measures did not extend, on the flanks of the Dartmoor granite, to the south of the Bovey basin. Since that time, however, Mr. Austen has traced, and laid down on a map communicated to the Geological Society, a considerable band of the culm series, skirting the granite from the north-west end of the Bovey basin to the hills west of Ashburton and Buckfastleigh.

tified, as well as unstratified rocks, with which they come in contact. The great series of rocks, therefore, which occupy this third region, are the newest deposits of our north and south section : and without prejudging their place in the British system, we may describe them conveniently as the culmiferous series, inasmuch as all the culm works of the county have been opened in them.

The extent and true geological position of this great deposit had been generally misunderstood ; for though certain beds of culm had been long known and extensively worked in North Devon, yet they had always been described as mere bands subordinate to the old greywacké system ; and had never been regarded either as occupying a great overlying trough, or as composing a distinct formation. Hence, also, the black limestones which appear on both sides of the great trough and form a part of the base of the culm-series, had been confounded with the other calcareous bands of the inferior groups.

4th. The *fourth region* into which we divide the county of Devon is occupied by the granitic rocks extending through the whole of Dartmoor.

5th. The *fifth* and last *region* includes all the remaining portion of the county ; bounded towards the north, partly by the granite of Dartmoor, and partly by the southern skirt of the culm measures ; and towards the south, by the long line of cliffs extending from Babacombe Bay to the west side of Plymouth Sound.

We think that the five regions, above enumerated, form natural subdivisions, —not laid down artificially, to facilitate description, but well characterized, both by their geographical features and their physical structure.

Passing over the first region, we shall proceed to describe the second or hilly region of the north coast ; showing, by help of natural sections, into what groups it may be conveniently subdivided. We purpose afterwards, in like manner, briefly to describe the fifth or southern region, to establish its subdivisions, and to bring them, as far as we are able, into comparison with the subdivisions of the second region. We shall then be prepared to describe the culmiferous rocks of the third region, and to show the relation they bear to all the rocks against which they abut, or on which they rest. In this way, after briefly noticing the general position of the Dartmoor granite, among the surrounding strata, and the characteristic phenomena at its junction with them, we hope to determine the whole sequence of the formations between the north and south coast of the county.

Our task does not, however, terminate here ; for by help of all the analogies with which we are acquainted, and more especially by help of the structure and organic remains of the several formations, we shall, in future communications, endeavour to bring them into comparison with the older groups of other

regions. Before this can be effected, much no doubt remains to be done. We possess large materials, bearing on these questions, which have as yet been very imperfectly examined. All we can do at present is, to make a first approximation to the solution of these difficult questions. That they press upon us for an answer cannot be doubted, when we consider that no one has yet attempted any rigid comparison between the older rocks of Cumberland, Wales, and Devonshire; that the antiquity of the slate rocks of Devonshire and Cornwall has generally been estimated by their mineral characters or by their vicinity to the granite—means which are not merely inconclusive, but often lead to conclusions which are absolutely false; and lastly, that the culmiferous series (occupying more than one-third of the whole superficial extent of Devonshire) has, under the name of greywacké, been confounded with formations, to some of which, at least, it bears no analogy, either in position, mineral structure, or organic remains.

Chap. II.—*Successive Deposits between the North Coast of Devon and the Culmiferous Series.*

Before we attempt any description or classification of these several deposits, we think it expedient to give a general account of their extent, and the places they occupy in the actual sections of the country. It will be seen, that our boundary lines (Map, Pl. L.) inclose a small portion of the north-west corner of Somersetshire, which is too intimately connected with our second region to be entirely overlooked. Our examination commenced with the northern part of the Quantock Hills, which, although beyond the limits of the country indicated in the preceding portion of the paper, must also be briefly noticed. The north-eastern flanks of these hills are composed of a soft, unctuous slate, not unusually of a red colour, here and there highly calcareous, and sometimes passing into thick, irregular masses of limestone partaking of the prevailing colours of the neighbouring rock*. From beneath these, rises a system of beds which occupies the central and higher portions of the hills, and (as far as we could make out, from our hasty examination of a country so much covered with vegetation) is composed of hard, and sometimes coarse sandstone, alternating with more fissile, micaceous masses of finer structure, and with masses of soft, rotten slate, resembling the prevailing rocks of the upper group above de-

* In the language of the workmen, the thick beds of red limestone are called *trug*; and the thinner beds, after passing into a soft, glossy, unctuous slate, are called *pavey*. The soft, earthy slates generally pass, in Devonshire, under the name of *shillat*.

scribed on the north-eastern flanks of the principal ridge. In the northern portions of these hills (where they are highest and best-defined) the *strike* conforms to their principal direction; but further south, where they are lower and more expanded, the subordinate beds undulate, and seem to lose all regular bearing.

After crossing the plain of new red sandstone, which forms the western side of the Quantocks, we found a repetition of nearly the same rocks, viz. a series of reddish, soft slates, in some places highly calcareous, and containing beds of limestone, resting on an inferior system of harder texture, enclosing many beds of flagstone, shillat, and reddish sandstone, here and there almost passing into a conglomerate form. The upper series is well exhibited on the eastern skirts of Croydon Hill. The lower, with all its modifications, is finely exposed in Croydon Hill, Grabbist Hill, and North Hill, and is of very great thickness. In several parts of North Hill and Grabbist Hill, the strata are violently contorted, and the lines of disturbance are in various directions; yet on the whole, the strike of the beds seems to be nearly W.N.W. Part of Croydon Hill is thrown up in the form of a great elliptical dome, and the calcareous bands form a portion of an elliptical curve sweeping round the eastern extremity of its longer axis; and it perhaps deserves remark, that the axis is nearly parallel to the principal direction of the strata in North Hill and Grabbist Hill.

In this part of Somersetshire, the strata are contorted, the hills discontinuous, and the sections broken; yet the main fact, we have just stated, viz. the existence of a lower formation of coarse, arenaceous rock, often of a red colour and of an upper formation of calcareous slate, is established on sufficiently clear evidence, and leads us at once to consider the structure of North Devon.

The strata of North Hill are cut off from the coast by the valley of Porlock, which probably owes its origin to one of the great breaks or contortions, that mark the neighbouring region. The same system of beds, however, reappears on the west side of the bay, and is continued to a headland a little north-east of Lynmouth, forming a noble succession of red cliffs, and a well-defined ridge running parallel to the coast. Along the whole of this line, the beds strike about W.N.W., and dip into the sea, at a great angle, about N.N E.

If we make a traverse to the south from any part of the coast above mentioned, west of Porlock, we find at the distance of a few miles, though the strike continues about W.N.W., that the prevailing dip is reversed to the south. From this we discover, that an anticlinal line runs nearly parallel to the strike of the beds, and to the mean direction of the coast between Porlock and Countesbury Foreland. We further discover, that the mean direction of

the beautiful gorge down which the waters of Exmoor Forest descend to Linton, very nearly represents the direction of the anticlinal. A great feature like this may almost always be traced to some geological cause; and we find that the strata bordering on the gorge are nearly horizontal, while those to the north and south of it continue for many miles to have a prevailing dip respectively to the N.N.E. and S.S.W. The pommel of the saddle is not represented by a mere line, but by a broad space, within which the strata are nearly horizontal, and on opposite sides of which their dip is not only reversed, but greatly increased in quantity*. We may however state, with sufficient correctness, that the anticlinal line passes into the sea down the Valley of Rocks immediately west of Linton: for to the south of it, the beds acquire a steady southern dip; and to the north of it, though their dip for some way is very slight, a little beyond Linton they have, after some remarkable contortions, a high northern pitch. It is in consequence of this anticlinal position, that the coarse red arenaceous greywacké of North Hill, and of the cliffs between Porlock and Countesbury, is repeated over again, and occupies the whole succession of great red cliffs, extending from the west end of the Valley of Rocks to Combe Martin†. Were we to draw two lines respectively from the Valley of Rocks and Combe Martin, in the direction of the strike, we should nearly define the range of the arenaceous system on the south side of the Lyne, as far as Exmoor Forest; and thence the same system is traced (though not without some interruptions) through the highest peaks of Somersetshire into Croydon Hill.

After the preceding statements, it must be obvious, that we class the gorge of the Lyne among *valleys of elevation*. The causes, whatsoever they were, which produced the anticlinal lines and regular strike of North Devon, acted also, in the region just described, on the hard, brittle beds of red, arenaceous greywacké; and thereby produced an enormous rupture along the line of contrary flexure, to which the present gorges of the Lyne owed their first origin‡.

This region illustrates also another point in geology:—when chains are well-defined, the anticlinal lines are generally steady in their direction, and nearly coincident with the strike of the beds; but the end of a chain of hills,

* See the north end of Section 1 (Pl. LI.), from the Foreland near Linton to Dartmoor. † Ibid.

‡ *Valleys of elevation* (or, in other words, anticlinal lines traced through a country, not by ridges but by depressions originating in a fracture of the strata) are by no means uncommon among our older formations. They abound in the highest parts of North Wales; and in Merionethshire, an anticlinal line, about thirty miles long, is traced through its whole course by a succession of valleys. The actual pommel of the saddle (in the form of an anticlinal ridge) is only seen in one single spot.

or the outskirts of a physical region (such, for example, as the termination of the old rocks of Somerset and Devon, in the plain of the new red sandstone) is often marked by the greatest possible confusion, both in the direction and dip of the strata. The reason of this is obvious; for in such situations, the strata are exhibited in the very regions, in which antagonist forces were just on the point of overcoming those very forces from which the chains themselves, and all their accidents, were originally derived. This remark is, we think, well illustrated by the irregular undulations of North Hill, the interruption of Porlock Bay, the dome-like elevation of Croydon Hill, and, perhaps we may add, by the outlying ridge of the Quantocks.

It appears from what we have stated, that the lowest beds in this part of North Devon must be sought in the anticlinal region, and in the deep gorge of the Lyne. Accordingly, we there find a gradual passage into a lower system of soft, chloritic, fossiliferous slates, alternating with many harder, arenaceous bands. The upper part of the group is seen in the horizontal beds of the Valley of Rocks; the lower portion only in ascending the deep cleft of the Lyne. It is interesting, as forming the base of the old rocks of North Devon, and as being the lowest fossiliferous and calcareous slaty group; but its whole thickness is nowhere exposed to view, and we are left to other evidence as to its place in a descending series of formations.

We have before stated, that the red arenaceous system, with a steady dip (about S. by W., or S.S.W.), extends from the Valley of Rocks to Combe Martin. Just as we turn the headland leading into the Combe, a new group presents itself, constituting a succession of cliffs of different colour and form, the highest beds of which run into the sea about a mile west of Ilfracombe Harbour. This group, near the coast, contains eight or nine distinct calcareous bands, some of which are extensively worked for use; and many parts of it are highly fossiliferous. Its average breadth is about a mile and a half, measured horizontally and in a direction transverse to the strike; and it may be traced without difficulty into the interior (especially by help of the calcareous bands), first in a direction about S.S.E., then along the south flank of Exmoor Forest, in a direction nearly east and west. We afterwards meet with it along the water-shed crossing the turnpike-road from Minehead to Dulverton; and from that point (as before stated) it forms a great elliptical curve, sweeping round the eastern and north-eastern flanks of Croydon Hill. In this way we have a complete proof that the calcareous slates of Somersetshire, bordering on the Croydon hills, are the equivalents of those at Ilfracombe; and that the coarse red greywacké of Croydon Hill is also the equivalent of the red beds of the same structure on the coast between Combe Martin and the Valley of the

Rocks. This is precisely the same conclusion which we attain, in a different way, by first identifying the formations of Croydon Hill with those of North Hill, and so linking them with the coarse red rocks of the Devon coast, on the north side of the great anticlinal line of the Lyne*. The identification of the Ilfracombe system with the calcareous bands on the north-east flanks of the Quantocks, is not so complete; but it is, we think, highly probable, both from the lie of the country and the structure of the component beds. We have been the more particular in the preceding account, because it seems necessary to a clear understanding of the stratification of the region, and of the evidence presented by our transverse section.

The calcareous slate system of Ilfracombe, though interrupted by some violent contortions, dips, on the whole, to a point a few degrees west of south; and is succeeded, in the ascending order, by a great formation of rocks, in which a slaty character predominates more decidedly than in any of the preceding systems. This slate group generally dips at a high angle, and is of very great thickness; less, however, than might at first be supposed from its breadth, which is not less than four or five miles, inasmuch as many of its beds are repeated again and again by a succession of anticlinal and synclinal planes, ranging exactly with the strike of the country. It may be separated into two natural divisions: the *lower* abounding in a greenish chloritic schist, much intersected by quartz veins, and generally too soft and shivery to be used for roofing-slate; the *upper* containing also many soft fissile beds, resembling those just mentioned, but abounding also in thick, arenaceous beds, some of which are red and variegated, like the hard arenaceous bands east of Combe Martin, while others are gray and greenish gray. The glossy slates of the lower division terminate on the coast near the north end of Morte Bay; and some hard, greenish gray, or purple, micaceous flagstones, form the highest portions of the upper division, and are, by a well-defined southern dip, carried under the next succeeding headland of Baggy Point.

* If we are correct in identifying the red sandstones and hard arenaceous rocks of Croydon Hill, Grabbist Hill, and North Hill; and if we have correctly linked the rocks of North Hill with the red arenaceous rocks which strike from Porlock Bay to the Foreland; it then follows inevitably, that the red sandstone of the Foreland is the equivalent of the red sandstone between the Valley of Rocks and Combe Martin. Mr. De la Beche (Report on the Geology of Devon and Cornwall, 1839) places the red sandstone of the Foreland *under* the Linton system. We cannot at present accept this interpretation of what we allow to be a difficult and disturbed natural section. Our interpretation of the phenomena is explained in the text, and illustrated by the accompanying section (Pl. LI. fig. 1.). The question is, fortunately, one of no real moment, as there is now no difference of opinion respecting the geological position of the several groups of strata with organic remains, upon which all general questions of classification must ultimately depend.

The beds of the great double group, just described, range across North Devon, along with the calcareous system on which they rest, and are finely exposed in the cuttings of the new road from Minehead to Dulverton, where they agree so well with the corresponding parts of the coast section, that nearly the same description might serve for both localities. The upper arenaceous beds are well seen in the river gorges to the north of Dulverton. We have not traced this system further to the east; but it appears to range through Brandon Hill, and the elevated ground on the south side of the calcareous bands of Croydon Hill, towards the plain of the new red sandstone.

The fifth and last group of the northern region of Devon, commences on the coast, in the headland called Baggy Point, where the beds dip S.S.W. at a great angle. Many of them are composed of an arenaceous and siliceous flagstone, of a brownish gray colour; but they are neither so thick nor so firm in texture as the siliceous beds of the lower group, and are distinguished from them also by ferruginous earthy bands, with numerous casts of organic remains, which are wanting in the former. In rounding Santon Down, we find a system of brown earthy slates and flagstones thrown into a succession of violent undulations; but on skirting the marshes still further towards the south, in the direction of Barnstaple, they acquire a steady dip to a point about south by west; and with the same dip, they are seen in some low earthy cliffs opposite Fremington Pill, near Barnstaple, on the south side of the river, and are thereby carried under the base of the great culmiferous series.

By referring to the accompanying Map, it will be seen, that the breadth of this fifth group, near the coast, measured on a line perpendicular to the strike, is not less than three or four miles. Following its range towards the east, it is seen underlying the culmiferous rocks to the north of South Molton; and the upper portion of it passes under the same rocks between Dulverton and Ex Bridge. (See Sect. fig. 4. Pl. LI.). Still further in the prolongation of the line of strike towards the east, the mineral character of the group undergoes a considerable change. The brown and gray arenaceous flagstones of its inferior portion, often pass into a red sandstone, hardly to be distinguished from the red sandstone of the second group; and its upper portion at the same time passes into a beautiful bright red and variegated earthy slate, which underlies the culm series, and is well exposed in a rivulet between Trace Bridge and Stawley. Considered as a whole, this fifth group is distinguished by its lower arenaceous flagstones, with ferruginous bands of rottenstone, full of organic remains; by the dull colour and more earthy texture of its slaty beds; by its brown flagstones, covered with impressions of encrinital stems; by its calcareous bands, sometimes passing into great lenticular masses (provincially called

junks) of nearly pure limestone; and by its numerous, but generally ill-preserved, fossils. Many parts of it so exactly resemble the Caradoc sandstone, that we were, at first sight, led to place it provisionally in that part of the Silurian system.

Mineral Structure, Thickness, Fossils, &c. of the preceding Five Groups.

In the preceding sketch, we have endeavoured to convey a true notion of the distribution of the natural groups into which the strata of a portion of North Devon may be divided, and of the evidence we have of their order of superposition. We must now add a few words on their structure, fossils, and other characters, by help of which, we may hope eventually to compare them with other rocks of the British series. (See Map, Pl. L., and Sections 1, 2, and 4, Pl. LI.)

1. Our lowest group, as above stated, is seen in the lower part of the Valley of the Lyne, and in the Valley of Rocks, and the cliffs west of Linton. Ascending the valley from Lynmouth, the beds on both sides the river dip nearly north, but at a small angle*. The most striking of them are composed of a hard, close-grained, greenish and reddish siliceous sandstone, much intersected by nearly vertical, transverse joints, slightly micaceous, and here and there traversed by earthy, cellular bands, marking the dip, and full of casts of fossils. These harder beds alternate with and pass into soft fissile and chloritic beds, much intersected by planes of cleavage, which hang towards the south—a direction opposite to the true dip of the beds. A little below Waters'-meet, the beds are so much contorted that it is difficult to draw any conclusions from their dip; and some of them are highly calcareous and fossiliferous. The organic remains are,

* The same dip is seen in the cliffs on both sides of Lynmouth, and extends a considerable way both to the east and west. Following the base of the cliff towards the Foreland, this northern dip continues about half a mile; and we reach a point where, in the lower part of the cliff, is a hard, bluish flagstone, with calcareous veins and some obscure fossils; and in the upper, a hard, reddish gray gritstone, with many quartz veins. We supposed, when on the spot, that these calcareous beds were a prolongation (by the northern dip) of some similar beds seen in ascending the gorge of the East Lyne. Beyond the point of the coast above mentioned, commence some remarkable contortions; and the dip at the base of the cliff is reversed to the south, for about a quarter of a mile, when a series of magnificent contortions, by which the beds are almost twisted into re-entering curves, and enormous masses are almost compressed into ellipsoids, are again seen in the cliffs, where the coast turns and trends more directly towards the north. Beyond this part of the cliff, there is a steady dip to a point about N.N.E., and at a great angle, and it is continued into the reefs at the furthest point of the Foreland. Considering the enormous thickness of the coarse red grits which extend into the Foreland, we do not see how they can be correctly packed *under* the Linton calcareous group, consistently with the dips above indicated. Our interpretation probably requires a *downcast fault to the north*, cutting through the contorted beds. Mr. De la Beche's explanation seems, on the contrary, to require an *upcast fault* to the north. In a previous note (p. 642) we have endeavoured to show that our explanation harmonizes with the general structure of the district.

however, almost entirely destroyed by cleavage-planes cutting obliquely through them. On the banks of the tributary of the Lyne, south from Waters'-meet, the slates become so highly calcareous, that an attempt was made to burn them for lime; and we have been informed, that along the same strike of country, similar beds have been found in Exmoor Forest. In the higher parts of this group, the hard gritty and siliceous bands, generally of a dull gray colour, continue to alternate with the slaty and chloritic beds, and are in some places very fossiliferous, as may be seen in the Valley of Rocks, and at the great Castle-Rock on the coast; near which the series ends—being carried by a southern dip under the second group. A passage, indeed, seems to be made into the red upper group, through the intervention of some bands of red, earthy schist, alternating with micaceous and siliceous flagstone. In the absence of any visible base, it is impossible to estimate the entire thickness of the formation, we have been describing; but from the lowest beds in the gorge of the Lyne to the crests of the hills overhanging the Valley of Rocks, and still more to the beds of passage above indicated, there is a thickness of many hundred feet. Among the fossils obtained from this group (unfortunately in the form only of casts, and generally ill-preserved) we have many corals, an Orthis, and two Spirifers; but as we shall return to this subject, we will not, for the present, attempt to describe our imperfect list.

2. The most striking characters of the second group are its coarse texture, and red or purple colour. These colours are partly derived from the red oxide of iron diffused through the beds, and partly from the veins of the same mineral which traverse the cliffs, and are washed far and wide by the waters. Indeed, some of the beds themselves (where no veins intersect them) are so impregnated with an earthy oxide of iron, that they are dug up entire, and the richest parts of them are extracted for the furnaces*. Cases like these are, however, to be regarded as rare exceptions. The coarser beds are generally thick, irregularly jointed, and break into rude, shapeless, angular fragments; and their colours vary through white, gray, greenish gray, variegated, and purple, to deep red. The coarsest varieties, at North Hill and in some parts of the Quantocks, pass into a conglomerate of red sandstone, with quartz pebbles, not distinguishable from the conglomerates of the old red sandstone. Some of the hills west of Porlock are covered with a white sandstone of this formation, fragments of which lie bleaching on the moors, and might be mistaken, at first sight, for grits of the coal formation. The fine sandstones contain, however, fragments of clay-slate, and not unusually pass (through the intervention of purple, variegated, micaceous, flaggy grits, exactly like the flaggy beds of old red sandstone) into red slate, greywacké, and greywacké slate; among which, bands of fine, glossy clay-slate are here and there interpolated. Considered as a whole, and from mineral characters only, we might compare some parts of this group with the most characteristic portions of the old red sandstone. Other parts we might compare with the red arenaceous beds of St. Abb's Head and the Lammermuir chain; with the red sandstones and schists of the Longmynd, Lyth, and Haughmond Hills of Shropshire; and with some of the coarser portions of the Upper Cambrian System, as developed in South Wales.

The whole thickness is exposed only in the coast section; extending, as before stated, from the west side of the Castle Rock to Combe Martin. The dip is steadily towards the south; and there are, we believe, few breaks or dislocations by which the same beds are repeated over again. The breadth of the formation, measured transversely to the strike, is nearly three miles; the thickness of the group must, therefore, be very great. Considered as a whole, it is neither cal-

* There is a work of this kind on the south side of the red sandstone plain, about two miles from Timberscombe, in Somersetshire; and similar works were once carried on in the hills north of Combe Martin. (See Map.)

careous nor fossiliferous; but by these words, we mean to state only that we found no fossils in it, and that at least they are very rare. We must remember, however, that it is interpolated in a fossiliferous system; and that a better search might probably bring to light a few fossils among the finer strata, alternating with the coarser red sandstones.

3. The next group of calcareous and fossiliferous slate is of very complicated mineral structure. The first beds are coarse and siliceous, and contain fragments of large, heart-shaped, bivalve shells. These are succeeded by clay-slate, more or less arenaceous, all dipping, as before, about S.S.W., and at a considerable angle. Ascending by the valley of Combe Martin to Yellaton (a distance of about a mile and a half), we cross not less than eight or nine courses of highly calcareous slate, in some places passing into great bunches of bluish crystalline limestone, with many contemporaneous veins. The limestones have some traces of organic remains, which occur also in abundance, but generally as casts, in the neighbouring calcareous slate. One of these calcareous courses immediately south of Combe Martin, is not less than 60 feet thick. In general, they are much thinner; and none of them are very continuous in the direction of the beds; but contracting to an edge, and expanding, several times, along the line of strike, they occasionally appear more like huge lenticular masses of semi-crystalline limestone, interpolated irregularly among the calcareous slates, than true alternating beds. Four or five of these calcareous courses have been traced, by our friend Major Harding, through the headland which separates Combe Martin from Ilfracombe.

The cliffs on both sides of Ilfracombe Harbour are interesting, from their great complexity of structure. Some of them are made up of alternating strata of hard siliceous sandstone; and beds of soft, glossy, yellowish green, chloritic slate: others are composed of dark-coloured clay-slate, with quartz veins, alternating with hard quartzose beds. Some parts are devoid of calcareous matter; others abound in it; and among the earthy slates, west of the harbour, are thin bands of limestone, almost made up of encrinital stems. Among the calcareous slates, we find quartz veins, sometimes ranging in long stripes, nearly parallel to the beds; sometimes in irregular zig-zags nearly transverse to them; and in one or two instances thin veins of arragonite range nearly parallel to the strike. In the cliffs west of the harbour, where the structure is thus complicated, the beds are violently contorted: still further west, they acquire the prevailing dip (S.S.W.), by which the distinct courses of calcareous slate, with great lenticular masses of limestone, are brought down to the coast; and the whole mass plunges under the next higher group.

The phenomena of slaty cleavage may be studied among these cliffs to great advantage. The average dip of the beds is about 35° to the S.S.W.; and among all the more fissile beds, we have a cleavage dipping to the same point, but at a greater angle; perhaps on the average as much as 60° or 70°. These cleavages affect also the calcareous beds, and make it almost impossible to ascertain their true dip in the quarries, where the contiguous strata are not exposed. The cleavage planes are not merely posterior to the beds, but are of a date posterior to those movements which produced the contortions: for there are several places, where these planes pass, without deviation in their strike and inclination, through a succession of violently-contorted beds. We may remark, also, that when any part of these beds is brought into such a position, that the cleavage becomes a tangent plane, the fissile texture will then coincide with the true bedding of the rock, and again separate from it, as the contorted beds deviate from the unvarying cleavage course.

All the neighbouring coast is intersected by joints, often forming a succession of great parallel open fissures. Of such there are two sets,—one to which we give the name of *dip-joints* is nearly transverse to the strike, and most frequently in a vertical or very highly-inclined position; the other set (or *strike-joints*) is nearly coincident with the strike, and generally inclined at a

great angle to the planes of the strata, and hence, where the strata dip to the south, these joints generally underlie to the north. This double system of joints divides many parts of the beds into a great series of rhombohedral solids. The cleavage-planes, in no instance which we observed, were parallel to these joints. Hence, also, it follows, that the jointed structure and fissile structure are not to be confounded. Almost all solid rocks have more or less of a jointed structure; but a small number of them have a transverse fissile structure. The two structures may, and do often, coexist, but, in all descriptions of old rocks, ought to be carefully distinguished from one another.

Such are the phenomena presented by this group in the only sections in which the successive parts are well exhibited. In its range towards the east, it is for many miles very ill exposed; being much covered by the vegetation and alluvial matter near the flanks of the higher ridges formed of the harder beds of the second group. Between Timberscombe and Dulverton it crosses the road, as above stated, at the water-shed, and contains, at least, three distinct calcareous courses. Further east it again declines in elevation; and the calcareous portion skirting the south flank of Croydon Hill is principally represented by one very widely expanded course of limestone, which is extensively worked. To the east and north-east of Croydon Hill it is again subdivided into several distinct courses of calcareous slate and limestone. These are precisely the phenomena we might have expected in such a formation. The structure seems to be most complicated towards its western extremity. Assuming the breadth of the formation at a mile and a half, and the average dip at 35°, we shall (after deducting for a few local contortions) have a very great thickness for this group.

Stems of Encrinites and portions of corals are among the abundant fossils of this group. Some of the calcareous slates of Ilfracombe are almost covered with the *Favosites polymorpha*, which is so abundant in the Torbay limestone. There are in this group also a Producta, several species of Spirifers, and other fossils, to which we shall refer in the sequel.

4. We have little to add to what we have already said, respecting the structure of the next superior group. The lower portions, which abound in soft chloritic slates, exhibit very fine examples of slaty cleavage, as distinguished both from joints and planes of stratification. For example, in the cuttings for the new road in the hills south of Ilfracombe, the cleavage has a nearly uniform dip at a great angle to the S.S.W. or S. by W.; while the strata, as may be made out from the *stripe*, are here and there violently contorted. The same facts are still more clearly illustrated on the coast near Morte Point, and in descending into Morte Bay from the north. This part of the series abounds in large, white quartz veins; several of which affect a kind of rude parallelism to the strike of the beds, but others are in undefined oblique directions. They are all to be regarded as veins of segregation, by some means or other superinduced on the rock, during the passage into its present solid state.

The upper and more arenaceous portion of this group, occupying the middle and southern end of Morte Bay, is ill exposed on the coast; but it may be considered to terminate in some thick and very hard beds of gray, greenish gray, and purple-coloured sandstones, alternating with thin beds of chloritic and purple glossy slate. These beds may be traced along their strike through North Buckland, and thence, skirting the south end of the hills containing the old manganese works, towards Muddiford.

Notwithstanding the many contortions of the chloritic slates, and some undulations (especially as shown in the sections on the road from Dulverton to Minehead) of the upper and harder rocks, the prevailing dip is towards the south; and the whole thickness of this group is very great, perhaps greater than that of any of the other divisions into which we have separated the deposits, we are describing. In no part of it did we observe any organic remains.

5. There is no definite line of separation between this and the preceding group: for beds of

siliceous sandstone, resembling those last described, continue for some way as we ascend the hill which runs out into Baggy Point. Gradually, however, the alternating glossy slates almost disappear, and the strata put on the form of gray and brownish gray micaceous flagstones; and associated with them, near the top of the hill, are some cellular ferruginous bands, with numerous obscure casts of fossils.

Doubling Baggy Point and descending to the north side of Croyde Bay, slaty masses again abound, which, though very fossiliferous, and of much more earthy texture than those of the preceding group, have generally a true slaty cleavage. These cleavage-planes strike very nearly, though not always exactly, with the beds; and in this part of the coast they generally incline at a high angle towards the north, the prevailing dip of the strata being towards the south.

Phenomena of this kind are always instructive, and are more especially so on the coast of Santon Down, where the beds are highly fossiliferous and thrown into a succession of undulations.

In this part of the coast, many of the rocks conform so nearly to the mineral type of the lower division of the Silurian system, that the descriptions of the slaty varieties of the Caradoc sandstone of Shropshire and Herefordshire might be applied to this Devonian series, almost word for word.

The lower or middle portion of the group, we are describing, may be easily followed along its strike into the interior of the country; and there are two quarries in it which deserve notice. One of them, first noticed by Major Harding, is near the inn by the road-side at Marwood, and exposes a set of strong beds of brownish gray and greenish gray sandstone; at the partings of which are several ferruginous, cellular, and earthy bands with numerous casts of fossils. The other is at Sloly, nearly three miles north of Barnstaple, and close to the turnpike road. It deserves notice from the structure of its coarse and thick beds of greenish gray and brownish gray sandstone, separated by the bands of earthy slate and shale; and still more from the vegetable fossils discovered in it by Major Harding and the Rev. D. Williams, which will be described in another place. In both the above quarries the dip is almost south; but a little nearer Barnstaple, similar beds are reversed and thrown into undulations.

Lastly, the highest portion of our present group passes into a deposit of soft and rather earthy slates with subordinate bands of sandstone, and occupies generally a low tract of country skirting the northern boundary of the culm measures. It is very fossiliferous, and sometimes highly calcareous, passing, as before mentioned, into irregular masses (or *junks*) of limestone. These however, are seldom worked, in consequence of the immediate vicinity of the great open quarries of black limestone, found in the lower portion of the overlying formation.

In consequence of the undulations above noticed, and of the interruptions caused by the wide marshes bordering on the Barnstaple river, it is very difficult to make any approximation to the whole thickness of this group. We have, however, evidence enough to show, that the thickness must be very great, without taking into account the lower undulating masses. Beyond Dulverton, in its range towards the plain of the new red sandstone, it becomes much more ferruginous, and is greatly modified in mineral structure, as we have already pointed out.

Among the fossils of the lower part of this group (Marwood quarries) are shells of the genera *Cucullæa*, *Cypricardia*, and *Bellerophon*. One species very closely resembles *Bellerophon globatus* of the old red sandstone. Nearly on the same line (Sloly quarry) occur the vegetable impressions above noticed. By far the greatest number of fossils occur, however, in the upper part of this group; and among them, we noticed innumerable crinoidal stems, many fragments of Trilobites, Orthoceratites, Terebratulæ, many Spirifers, a few spined Productæ, &c. &c. A more detailed account of these fossils is reserved for a future communication.

Such are the groups into which we have divided the deposits in the northern region of Devonshire. They are founded on analogies of mineral structure, on superposition, and on the existence of successive calcareous and fossiliferous bands; and it is important (at least till they are better known) to keep them distinct from one another. Some of the lines we have drawn, are, perhaps, artificial and arbitrary; but so are some of those which divide our best known, secondary formations. Without something like the arrangement we have adopted, it would be difficult to give any clear description of the great deposits of the northern region; still less could we hope to bring them into comparison with the successive groups in South Devon. At all events, we have shown that all the groups above described are inferior to the culm-measures of our third region, a fact with which we were unacquainted, when we commenced our task.

Chap. III.—*Succession of Deposits between Dartmoor and the South Coast of Devon, &c. &c.*

(See Map, Pl. L., and Sections, Pl. LI.)

If a line be drawn (in a direction about east and west) from the limestone cliffs near Plymouth to the limestone cliffs of Berry Head, at the south end of Tor Bay, it will cut off the great south promontory of Devon, which terminates in three remarkable headlands,—Bolt Head, Prawle Point, and Start Point. Now, as in all this promontory the *strike* of the beds is nearly east and west, and the prevailing dip is south, it appeared to us that the coast-section from Plymouth to Bolt Head, and a corresponding section from Berry Head to Start Point, must probably cross the same succession of deposits. We examined both these sections, and our expectations were realized. North of the line above mentioned, the strike and dip of the strata are by no means regular. They gradually become affected by the granite of Dartmoor, and on doubling its southern end they are bent towards the N.E. In this way, rudely conforming to the mean boundary of the granite, they sweep round the south-eastern side of Dartmoor with a north-eastern strike and a prevailing south-eastern dip, as far as the basin of Bovey Tracey. If, however, we make a traverse from this side of the granite to the cliffs of Tor Bay, we gradually lose this regularity of strike and dip. The strata have been much disturbed at different periods, and exhibit many axes of elevation (probably derived from great protruding masses of trap) which conform to no given direction. The contorted beds of Tor Bay (which have been described in memoirs

read before this Society*) are fine examples of what we are here stating, and many others are exhibited in the interior of the district. In spite of this confusion, we easily ascertain that the limestone rocks of Tor Bay and Berry Head belong to the highest strata of the older formations on the south-eastern side of Dartmoor. Now the limestone series at Berry Head (both from the evidence of the coast section and from the evidence of the section along the estuary of the Dart) is found to plunge under the slate region, which is expanded through the great south promontory. From which it follows, that a section first from Dartmoor to Berry Head, and then continued from Berry Head (coastwise) to Start Point, must cross all the old stratified deposits of South Devon. We think there is no doubt that the Plymouth limestone is exactly or very nearly the equivalent of the limestone of Berry Head. Hence (after what has been said respecting the strike and dip of the country) it must be obvious, that a transverse section from the granite of Dartmoor to the Plymouth limestone, and then continued from that limestone (coastwise) to Bolt Head or Start Point, would also give a nearly perfect series of the strata of South Devon. We examined the several lines above-mentioned; and in the essential details of the corresponding parts, they appeared to agree perfectly, some of the lowest beds only being wanting on the line from Dartmoor to Plymouth. Our limits preclude minute details; but we will, in a few words, endeavour to describe the facts which are exhibited on those lines of section, and seem essential to our classification.

1.—*Sections from the east side of Dartmoor to Berry Head, &c. &c.*

Commencing with the section from Dartmoor to Torbay, we pass over the stratified rocks immediately in contact with the granite; for in that association, whatever part of the series they may belong to, (and under this remark we include the culm-measures as well as all the older formations,) they become so entirely metamorphic as to lose all their distinctive characters. But at a little distance from the granite, (for example, on the north side of Ivy Bridge, and on the east side of a line drawn from Ugborough to Buckfastleigh) there are extensive tracts of a rock which deserves notice. It is hard, brittle, and porcelaneous; sometimes passing into a compact felspar, sometimes into a flinty slate or Lydian stone, not unusually resembling the well-known altered coal-shales in contact with trap dykes. We have no doubt that these rocks have been indurated by the action of the granite, as in following them in the ascending order, they gradually pass into the common dark-coloured roofing-slate of this country. Higher in the ascending section, the slates become calcareous, and here and there pass into masses of bluish gray limestone. Two or three distinct bands of this kind may be seen in the neighbourhood of Ugborough; and in the range of the strata northwards, the calcareous portions unite into one leading mass, and swell out so much as to make, in the neighbourhood of Ashburton, a great feature in the district. The

* See Mr. De la Beche's Memoirs, Transactions of Geological Society, 2nd Series, vol. iii. part 1, p. 160.

Ashburton limestone contains a few corals and some unascertained casts of shells. Immediately under one of the coral beds of the Ashburton quarries, is a remarkable band of highly carbonaceous black shale. The neighbouring beds of limestone are of a dark colour and very much resemble true carboniferous limestone. They do not, however, burn (like the dark beds of mountain limestone) into white lime, and therefore do not derive their chief colouring matter from carbon*.

Still higher in the ascending section, the calcareous bands disappear, and we have again a succession of soft glossy slates (in some places used for roofing), with very few distinctive mineral characters, and generally without any cleavage, separate from the laminæ of deposit. The upper part of this series again becomes calcareous; obscure casts of organic remains are found abundantly in some parts of it; and among indurated slates associated with trap, which seem to underlie the limestone of Newton Bushel, are fine impressions of an undescribed Trilobite.

The fossiliferous slaty beds introduce the great upper or Torbay limestone, which is magnificently developed both in the interior of the country and on the coast.

The nature of this communication not admitting of minute details, we have so far omitted all description of the various trap rocks which occur on our lines of section. Some are of the nature of dykes, and appear to have been protruded at different times prior to the eruption of the granite, which (as was pointed out by Mr. Austen) they never penetrate. Other trappean masses are not only parallel to the beds of schist, but are associated with plutonic sediment passing into, and alternating with, the slate rocks. In such cases, we concluded (as we had done before in numberless instances seen in Cumberland and Wales) that the plutonic and aqueous rocks were contemporaneous.

In the slaty series between the Ashburton bands and the great upper limestone on the east side of South Devon, we may often remark, that the higher portions become arenaceous, and sometimes pass into a coarse red sandstone, not to be distinguished from the old red sandstone. Instances of this kind are exposed in Babbacombe Bay, in the hills N.W. of Totness, and on the banks of the Dart. Neither is this series altogether devoid of calcareous matter and beds of limestone, as may be seen in several sections to the north-west of Totness. We considered these beds as mere offsets from the great limestone; but Mr. Austen has since shown us sections, which prove that at least some of them are true members of the middle slate series. They cannot, we believe, be traced far on the lines of *strike*, as many transverse sections give no indication of them. A more important fact, however, in the history of this great slaty group is the frequent occurrence of organic remains in the beds as they approach the great upper limestone. This fact (of which examples may be seen near Ogwell, near Pomeroy Castle, in the cliffs east of Torquay, at Mudstone Sands, &c. &c.) shows that the slates and overlying limestone belong to one uninterrupted series of deposits; for in other situations the slates are very rarely fossiliferous.

The upper limestone in the eastern parts of South Devon generally appears in the form of great unconnected masses, more or less tabular, crowning the hills and surmounted by no newer deposits. In its structure, as well as

* Among the shales which divide the beds of the great upper limestone of South Devon, about two miles north of Totness, we found a few thin laminæ of bright coal. Examples of this kind are, we believe, very rare; but there are similar appearances in the Hooe limestone quarry, near Plymouth.

position, it strongly reminded us of the masses of great scar limestone which rest unconformably on the slate rocks of Cumberland and Westmoreland. From this circumstance, and perhaps still more from some of its fossils, it has been occasionally confounded with the carboniferous limestone. But a portion, at least, of its fossils, more especially its corals, separate it from that limestone; and the association of its lower beds with calcareous slates passing into the lower slaty system of South Devon, entirely preclude it from being grouped with any part of the true carboniferous system. The coast sections, however, seem to put the question out of all doubt. We have no hesitation in identifying the great limestones of Newton Bushel, Babbacombe Bay, and Torbay. Now the great limestone at the south end of Torbay, after exhibiting a number of contortions, and spreading out into a succession of mural precipices at Berry Head, is finally (at Mudstone sands) bent into a great arch which brings up the lower calcareous slates on which it rests, and causes the southern flap of the great limestone saddle to dip under the slate formation which is expanded towards the south along the shores of Start Bay. The same order of superposition is also indicated at Galmpton Creek on the eastern shore of the Dart, as well as at intermediate spots along the southern boundary of the limestone. (See Section 6.)

Thus we find, that the great upper limestone of South Devon is fairly interpolated between two great groups of slate rocks. Under such circumstances we are not surprised to discover that the calcareous beds have a continual tendency to thin out and come to an edge. This phenomenon (as also in North Devon) is best seen in the line of strike. Sometimes, however, we may see the beds thinning off in the line of dip; so that a mass of limestone will, in a vertical section, look like an acute wedge, driven in between the laminæ of the slates. Cases of this kind do not produce any ambiguity, as the longer dimension of these wedges of limestone is always in the direction of the dip. The great limestone of Berry Head thins off in the direction of the Dart, and beyond the river seems to be replaced by several thin calcareous bands, alternating with the slate. Further west, these calcareous bands disappear: but a similar system, very nearly, if not exactly, on the same line of strike, is revived, and becomes of great thickness, on approaching Plymouth Sound*.

* Our accompanying section (Pl. LI., fig. 8.) shows the lower (or Ashburton) limestone. The beds below this limestone are concealed by an overlying band of culm-measures, as we afterwards learnt from a section by Mr. Austen, and have represented on his authority. The small trough of culm-measures overlying the great upper limestone was observed by us in 1836, and is alluded to at its proper place in the text.

2.—*Section from Dartmoor to the Plymouth Limestone, &c.*

(Pl. LI., fig. 9.)

If we cross the country from the south end of Dartmoor to Plymouth, we have a less perfect section than that above described, for the lower calcareous, or Ashburton, bands have almost disappeared. This may be easily accounted for; as even the thickest bands of the limestones, which are interpolated in the slate series, continually thin off; and in this case some of them may have been cut away by the encroachment of the granite.

Commencing with the boundary of the granite, we first meet with highly altered slates penetrated by granite veins, and tilted at a great angle. These, through various gradations, pass into the hard slates of Ivy Bridge, which, in the ascending order, finally pass into the ordinary dark lead-coloured slates, exactly like the courses overlying the Ashburton limestone.

In most parts of South Devon, slates are obtained from planes parallel to the laminæ of deposit; and, generally speaking, the transverse planes of slaty cleavage are incomparably less developed than among the schistose rocks of North Devon. But in a quarry about two miles south-west of Ugborough, we found very instructive examples of transverse cleavage, the planes of which had the exact strike of the beds, but were inclined at a much greater angle. Other, more inclined beds (both in the same and neighbouring quarries), were gradually brought into a position nearly coincident with that of the slaty structure, and then ceased to show any oblique cleavage planes; a fact, which clearly shows, that the cleavage planes were superinduced on the beds after their dislocation. We remarked, also, that the best slates were obtained, not from the laminæ of deposit, but from the oblique planes.

Near Ridgeway (on the Plymouth road) are several courses of trap, which range very nearly with the beds; and a little to the north are quarries of slate, associated with trap. One of them gives some obscure traces of an oblique cleavage, and exposes purple and dark leaden-coloured slates, which are much indurated, and spotted exactly like the altered chiastolite slates of Cumberland. On the south side of the quarry, close to the trap, is a chloritic slate, with a few crystals of felspar; yet this chloritic slate seems, by most regular gradations, to pass into the ordinary dark-coloured slate. We need not dwell on details familiar to all who have examined the great slaty regions of England, but state at once, that, by a regular dip to the south, the whole slate series is carried under the Plymouth limestone.

In other respects this and the preceding section agree in their general details.

The Plymouth limestone is composed of a great succession of thick, well-defined beds, dipping south, at an angle averaging at least 30° or 35°; and as its superficial breadth amounts in some places nearly to a mile, and it is not repeated by any great contortions, its thickness must be very considerable. Notwithstanding this, if we follow it to the east, along the line of strike, it comes to an edge at the distance of about four miles; and if we follow it in the opposite direction to the Cornish side of the Sound, it thins off still more rapidly; so that before we reach White Sand Bay, it has dwindled down to a few inconsiderable red beds of calcareous sandstone, containing Encrinites and other fossils; and further along the Cornish coast we lose all traces of it. A few masses of limestone, comparatively of inconsiderable extent and thickness, break out here and there, nearly on the line of strike between Plymouth and Berry Head, and seem to represent, in

a degenerate form, the great upper limestone of South Devon. At Plymouth the strike is very nearly east and west; but following the strata towards the east, we find them gradually deflecting a few degrees towards the north, which necessarily throws the limestone of Berry Head a little to the north of the Plymouth limestone.

Before we proceed to describe our remaining sections, we may briefly notice some of the characters of the South Devon limestones.

1. Where the sections are complete, they are interpolated in a great slaty series, and, indeed, very often pass into mere calcareous slates, subordinate to the general mass: parts even of the Plymouth limestone pass into mere calcareous slates. Its bottom beds pass into the strata on which they rest: its upper beds, in like manner, are exactly parallel to, and pass into, those by which they are overlaid. Hence, the present inclined position of the calcareous masses is due to the same causes which produced the present position of the slates.

2. The want of continuity in the limestones proves, that the causes which produced them acted less generally than the mechanical causes that gave rise to the layers of mud and sand out of which the slate series originated. It is difficult to speculate about the origin of calcareous slates where organic remains are almost wanting; but many parts of the upper limestone seem to be, in a great measure, due to the action of animals which once inhabited shells and corals. Now, the coral reefs and shell beds of the ancient sea must have been formed at the same inclination with the beds of sand and mud which were contemporaneous with them, and consequently were once nearly level.

3. There is a strong resemblance in the mineral structure of all the upper limestones of South Devon: at one extreme they are earthy and slaty; at the other perfectly crystalline. The most crystalline portions seem to have been formed about masses of abraded corals; and many of the hardest and thickest beds have more or less of a brecciated structure, as may be seen in some of the well-known Devon marbles. A colour derived from red oxide of iron is often irregularly impressed on the beds of limestone; and as the same colours are found in the next overlying group, as well as in some of the beds, inferior to the great limestone, this circumstance often produces a striking appearance in the range of the deposit through the country. The limestone was probably consolidated sooner than the slate, and hence may have offered planes of greater resistance, during successive periods of elevation. It is to this cause that we attribute the existence of some flexures in the inferior slates, which hardly seem to affect the great overlying masses of limestone, and produce what we regard as a deceptive appearance of discordant stratification. What makes this explanation more probable is the fact, that the thin beds of lime-

stone, and the calcareous slates, partake of all the complicated flexures of the slate series. The contorted beds of Purbeck limestone, associated with tabular masses of Portland rock, are examples of similar phenomena among secondary strata.

4. In some of the larger masses of limestone, the crystalline action, during the process of solidification, has almost obliterated every trace of deposit. All of them are more or less traversed by open joints; and some of the Plymouth beds are intersected by vertical north and south *dip-joints* of great regularity. The limestones are also occasionally divided into laminæ by oblique lines of cleavage, like those before noticed near Ilfracombe. Fine examples of this structure occur in several places north of Totness, and in the hills on the east side of Brixham; and the phenomena are the more remarkable, because an oblique slaty cleavage is very rarely seen among the neighbouring slate rocks. A certain quantity of calcareous matter seems in some instances to favour the development of this structure. For example; along the whole course of the Dart below Totness, the beds are generally without the least trace of an oblique slaty cleavage; but at East Cornworth Creek, a band of limestone is dislocated, dolomitized, and tilted at a great angle to the north, and is overlaid by some calcareous slates, which, near the beach, dip north, at a small angle, and have a distinct cleavage, inclining south at 45°. An exactly similar phenomenon may be seen in a small mass of calcareous slate imbedded in the great contorted red sandstone south of Plymouth; and there, also, the neighbouring strata are entirely without any transverse cleavage.

5. Before we quit the subject, we may notice one or two peculiarities of structure which are seen, though rarely, in South Devon, but very abundantly in the calcareous slates of the Cornish coast, west of Padstow. A slight change of colour generally marks the passage from one bed of slate to another; and hence, when several beds are cut through by an oblique cleavage plane, the surface of the slate so obtained is marked by a set of parallel stripes indicating the course of the beds. It is also clear, that slates obtained from laminæ parallel to the bedding can never show a striped surface of the same nature. But some slaty rocks (*e. g.* on the coast of South Devon, near Avon Mouth, and on the north coast of Cornwall) have what may be called a *false stripe*, which is at first sight very deceptive. They are derived from beds, the fine laminæ of which, in passing into a solid state, have been forced, by crystalline or mechanical forces, into wavy lines or flutings, sometimes nearly constant in their prevailing direction. Slates cleft off from such beds show stripes of colour parallel to the flutings, and are to be distinguished from the *true stripe* only by being worse defined and less uniform in their direction. That these

wavy lines were produced by tension, seems probable when we follow their course, and see it marked by minute joints, filled generally with quartz. We never saw an example of this false stripe in any roofing-slate of Wales or Cumberland; and the two kinds of stripe very seldom occur together. There are slates also from South Devon and the north coast of Cornwall, which give clear indications of a second cleavage plane affecting the elementary structure of the rock. We speak of a structure never, as far as we know, seen in the old Cambrian slates, and entirely distinct from the small double joints which so often separate individual beds into rhombohedral solids. This second cleavage is indicated by innumerable striæ (looking as if made by a sharp instrument like a very fine comb) running through the chloritic flakes that separate the laminations. With care, a cleavage (generally with a rough surface) may be obtained along these striæ, which occur indifferently both with the false and true stripe above described. The crystalline forces producing these striæ have also produced mechanical tension, as the striæ may be sometimes followed into minute partings, generally filled with quartz. On the river above Padstow are some beautiful examples of these complicated structures. A low cliff shows a set of contorted beds of calcareous slate traced by lines of organic remains: the beds are cut by oblique cleavage planes, producing striped slates. There is a second cleavage indicated by the parallel striæ, and the whole mass is divided into rhombohedral solids by a double set of open joints, which do not coincide either with the *striæ* or the *stripes*.

6. Lastly, before we proceed to the other sections, we may briefly notice the organic remains of the South Devon limestone. The corals in the Tor Bay, Newton Bushel, and Plymouth limestones, are very abundant; some of the species, more especially the beautiful feather-like coral (*Favosites polymorpha*), abounding at all the places above mentioned. Several species of *Spirifers*, *Terebratulæ*, and other shells, bivalve and univalve, are, we believe, common to them all, as might be expected among beds nearly of the same age; but we purpose to return to this subject, when we have better specific evidence. Some of the red coraline, calcareous slates of South Devon cannot be distinguished, either by structure or fossils, from the calcareous slates near Ilfracombe.

3.—*Coast Section from the Plymouth Limestone to Bolt Head**. (Pl. LI. fig. 5.)

1. We commence with this section, as offering the clearest evidence of superposition, and the best exposure of the successive beds; and after describing it, we shall briefly notice the corre-

* The section is supposed to be made on a straight line; to which the phenomena on the actual

sponding section from Berry Head to Start Point. The upper beds of limestone are seen at Mount Batten, and are overlaid by a great, red, arenaceous group, which may be subdivided as follows:

(1.) Over the limestone is a brown and yellow earthy slate, with pyritous stains and iron veins, some of which run, in the form of strings, nearly north and south. This mass alternates three times with beds of impure limestone; and the last bed occurs at Dunstan Point, where it thins out to an edge among the impure earthy slates. Several fossils have been found by Mr. Hennah in this part of the section, which may be considered as forming a kind of passage from the limestone to the superincumbent beds.

(2.) From Dunstan Point to Withy Hedge, the section shows a yellowish gray and bluish gray soft slate (*shillat*), with some quartz veins and coarse arenaceous bands.

(3.) Immediately over the preceding, and extending about three-quarters of a mile to Bovisand Bay, is a formation of bright red, and sometimes variegated sandstone, thick-bedded, and of coarse texture, but subdivided by bands of soft, glossy, red slate, and red micaceous flagstone. This division, in many parts, is exactly like the old red sandstone; and though thrown into violent contortions, it dips, on the whole, towards the south, and is of great thickness. It is overlaid by a reddish slate and flagstone, which gradually passes into the next superior division.

(4.) On the south side of Bovisand Bay, the slates become so earthy as to pass into the form of shale, with many small nodules of ironstone; and these are surmounted by variously-coloured earthy slates, alternating with reddish arenaceous bands, as seen in the cliffs of Crownall Bay, near the southern end of which is a patch of *new red conglomerate*, resting unconformably on the edges of the older strata†.

(5.) Beyond Crownall Bay is reddish slate and flagstone, and coarse red sandstone, occasionally contorted and penetrated by large quartz veins; the contortions chiefly seen in the strongest and coarsest beds. These gradually pass into reddish, grayish, and greenish gray chloritic slates, with hard quartzose bands and quartz veins. They strike about E. by N. towards Wembury, are of great thickness, and may be considered as beds of passage into the next superior group.

Though the upper limit of the preceding group is ill-defined, it is, on the whole, very distinctly marked by its coarse arenaceous bands and its prevailing red colour: and as its breadth, measured on a line transverse to the strike (from Mount Batten to the cliffs opposite the Mew Stone), is about three miles, and its average dip is not less than 35°, its thickness (notwithstanding the occasional contortions) must be very great. In its mineralogical characters, as well as in its thickness, it bears the closest resemblance to the red arenaceous rocks in the cliffs east of Combe Martin, the second group of our North Devon section.

2. The next group occupies the whole coast, from the cliffs opposite the Mew Stone to Hope Cove, near Bolt Tail—a distance, following the sinuosities of the coast, of more than twenty miles;

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coast section are referred by a series of lines drawn, from the respective points, parallel to the *strike*. Most of the places mentioned are found on the accompanying Map, Pl. L.

† Soon after our return from Devonshire, in 1836, we were informed by Dr. Moore, of Plymouth, that he had discovered organic remains in this part of the series. One of the authors revisited, along with that gentleman, this part of the coast in 1838. The fossils chiefly occur in the ironstone nodules, and are generally both obscure and waterworn. We remarked among his specimens a *Turbinolia* (?), and several other species of corals; two or three species of Orthoceratites; one or two casts of univalves; and some fragments of trilobites. Among the red cliffs of Crownall Bay, only to be approached at low water, are also many fossils, such as stems of Encrinites, fragments of corals, and comminuted shells, in an impure bed of reddish limestone, partly traversed with quartz veins. Near the calcareous bands were some transverse planes of slaty cleavage—appearances very rare in this part of Devonshire.

but the actual breadth of this group, measured on a line at right angles to the mean bearing of the beds, is not more than five or six miles.

The ascending section commences with the beds of passage above noticed; but to the south of the Yealm, the prevailing rocks are made up of a light gray and greenish gray chloritic schist, with quartz veins and quartzy concretions, and with subordinate hard arenaceous beds; and they prevail all the way to Stoke Point, with a steady dip about S.S.E. Several of these beds seem to strike into the cliffs between Stoke Point and Erme Mouth, and are repeated over again; but south of the Erme there is a steady ascending section for about two miles. In the cliff between the Avon and the mouth of the rivulet that descends from the north side of Ringmore, there are some anticlinal and synclinal lines, which we have attempted to represent in our section (Pl. LI. fig. 5.). On the whole, however, the ascending series gains towards the south. The prevailing rock is a fine, greenish gray, and leaden-coloured glossy schist, and the prevailing dip is about S.S.E. or S. by E. Near Fishery the beds exhibit the minute striæ which (in certain cases) we have considered as an indication of a *second cleavage*; here, however, there is no *principal cleavage* oblique to the bedding. The same series is also marked by beautiful flutings producing the *pseudo stripe*. Opposite Borough Island, near Avon Mouth in Bigbury Bay, the contortions are marked by a shattered cliff, with quartz veins and numerous joints; but further south, to a point about half a mile beyond Avon Mouth, there is a steady dip to the south, or south by east. We there meet with a synclinal line, which throws the beds into a trough, and produces a northern dip, that prevails, almost without interruption, to Hope Cove, where the whole group terminates abruptly against a formation of chlorite and mica slate.

Along the lines of strike, several of the more schistose beds are worked for roofing-slate, not generally of good quality; and, in all the instances that we saw, the slates are derived from planes parallel to the bedding. Immediately to the north of Hope Cove the beds are hard, quartzose, and dark-coloured; and on approaching the junction, they are altered and shattered, and penetrated in all directions by quartz veins. The actual junction is not parallel to either formation, but may be traced, at low water, in broken, zig-zag lines, showing the extreme derangement where the two masses are brought into contact. They seem mutually to wedge into and penetrate one another; and on the south side of the headland forming the junction, is a great mass of black-veined slate notched in among the beds of the older system.

From the lowest beds of this group to the highest (south of Avon Mouth), there is a breadth of four or five miles, measured on a line perpendicular to the strike. Hence, notwithstanding the contortions above noticed, the thickness of the deposit must be very great, especially when we consider the high mean inclination of the beds, which is greater than that of the preceding group.

The junctions on the Kingsbridge river take place on low ground, and give no new information; but if we follow the strike across the promontory from Hope Cove to Start Bay, we may see the two formations in the cliffs south of Tor Cross. The phenomena are there much more simple than at Hope Cove: neither the upper nor the lower system is unusually mineralized, and there is no confusion in the dip. The lower beds (composed, on that part of the coast, of fine quartzose, chloritic slate), though highly inclined, and in some places contorted, dip regularly towards the beds of the upper argillaceous slates, which also, for a considerable way, dip steadily to the north; but the immediate contact is unfortunately concealed.

3. To complete our section, it only remains for us to describe the crystalline group which extends to the extreme southern points of Devon.

Immediately to the south of the junction at Hope Cove, the crystalline slates are extremely

altered and mineralized. Some are yellow, earthy, and pyritous; others have become entirely earthy, are of a bright red colour, and, in their strike through the country, may be tracked through the fields by the red colour of the soil. Others, again, are partially indurated; and we may here and there extract from them hard, laminated bands of quartz and chlorite; and among them are irregular masses of earthy, pyritous, decomposing chlorite. The beds, however, soon acquire a more usual mineral structure; undulate towards the south; at Bolt Tail become nearly vertical; and afterwards pass, in a highly-inclined position, and after repeated undulations, to the extreme southern headlands. The prevailing dip is, however, to the north; and the strike is nearly true east and west.

In mineral structure, this group is entirely different from anything we have described in the sections either of North or South Devon. It is highly crystalline, and essentially composed of quartz, mica, and chlorite; the three minerals being frequently found together. Near its northern limit are some fine-grained, well-bedded rocks of blended quartz and chlorite, sometimes used as a building stone. More frequently it rises in large flaky masses, coated beautifully with mica and chlorite, and is used as a coarse flag-stone and coping-stone. In other places, from the occurrence of joints, the blocks are obtained in rude prisms, provincially called pencils, not unusually coated with red oxide of iron. The masses have both small and great contortions, so that it is difficult to find beds with smooth plane partings. Towards the south, however, (*e. g.* near Prawle Point,) we obtained beautiful and finely-laminated chlorite slate; and there are similar specimens of mica slate. On the whole, mica seems to abound more towards the southern, and chlorite towards the northern, extremity of the group; but the different varieties are so constantly mixed together, that it is impossible to divide the crystalline series into two formations. Felspar does not appear to exist as an essential constituent, nor did we see a single block to which we should give the name of gneiss. Pyrites is found in many of the beds; and oxide of iron not merely coats the joints, in some cases producing what the workmen call *iron pencil*, but the mineral exists in regular veins traversing the micaceous slate. The finest example is at Seacombe Sands, (near the mouth of the rivulet that descends from West Prawle,) where there is a vein of iron ore about four feet wide, and another smaller vein near it. It strikes nearly east and west, and underlies north, at an angle of 50°. Had it been more nearly vertical, it might, perhaps, have been worked to profit. On the east side of Gunnor Head, near Prawle Point, is a similar vein striking north and south, and underlying west at a great angle. Works have been opened in this vein, but are deserted. There is also an iron vein at Stenhall, on the east side of Bolt Head, and another about two miles further west.

This beautiful but anomalous group is probably of metamorphic structure, and had entirely escaped notice before the commencement of the elaborate county survey of Mr. De la Beche.

4.—*Section from Berry Head to Start Point.*

(Pl. LI. fig. 6.)

It only remains for us to describe in a few words the section connecting the Torbay limestone with the crystallized slates of Start Point. We have before stated that the limestone of Berry Head is thrown into an arch which brings up the inferior slates in the cliff of Mudstone Sands (p. 652); and the same arch is continued in the calcareous system towards Galmpton. The earthy slates of Mudstone Sands become more and more calcareous and fossiliferous in the ascending section, and so gradually pass into the limestone. In the same manner, on the north side of Galmpton Creek we

meet with the following ascending section: 1st, red sandstone and slate; 2nd, red, gray, and leaden-coloured earthy slate, almost passing into shale; 3rd, red and gray indurated shale and calcareous slate, with organic remains, and passing into the limestone. It is therefore obvious that the great limestone is intimately linked to the lower slaty system.

On the south side of the great saddle of Mudstone Sands the limestone again appears in the cliff at Sharkham Point with a high southern dip. The beds are confused and contorted by the passage of a great vein of iron that is worked, in the limestone, as far as Upton. A very little south of the iron vein is an interpolated mass or dyke of trap which breaks out, here and there, in some ridges ranging towards a point north of South Down. Beyond the trap, the beds of limestone are seen in the cliff with a very rapid dip to the south; but some of them appear to thin off and almost to come to an edge in the line of dip. The scale of our section enables us to represent these phenomena only in a general way. Notwithstanding the confusion on the coast produced partly by the iron vein and trap, the general mass of the limestone from Sharkham Point to Upper Brixham dips uneqivocally south, and so passes under the great slaty group that is expanded towards the mouth of the Dart. From all which we conclude, that the limestone of Berry Head has exactly the same general relations to the slate series of South Devon, as the Plymouth limestone*.

1. The beds immediately over the limestone of Sharkham Point are made up of a gray glossy slate, dipping at a great angle about south by east. They are succeeded by gray, greenish gray, and variegated soft earthy slate, alternating with sandy red and variegated micaceous flag-stone, which occasionally passes into coarse thick beds. Some of the beds exhibit remarkable contortions, and a series of specimens might be selected from them which would be almost identical with a corresponding series from the beds of the first group over the Plymouth limestone. The red sandstone does not, however, here predominate so much as it does near Plymouth.

The rocks above described prevail as far as Man Sands; on the south side of which is a soft silky gray slate, exhibiting at one single spot obscure traces of organic remains. This slate is overlaid, near the top of the high cliff going over to Scabbacombe Sands, by coarse arenaceous red rocks, like those above described. But they are again succeeded by a fine soft gray and greenish gray *shillat*, which, with many changes of texture and with many quartz veins and alternations of quartzose, arenaceous bands, is continued to the mouth of the Dart. On the whole, we think we may place the southern limit of our present group at Scabbacombe Sands: so defined, it is very nearly the representative of the red arenaceous group, above described, over the Plymouth limestone. It is, however, less perfectly developed than the corresponding Plymouth group, and, though on the same general line of *strike*, is a little further north, in consequence of a gradual change in the run of the beds.

The rocks south of Galmpton on the Dart agree in their general character with those of the present group; the boundary of which may be placed on the north side of Dartmouth, but, from

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* On the north side of Mudstone Sands, the calcareous beds overlying the slates have a distinct slaty cleavage, which does not affect the inferior slates at the top of the cliff. Among some slightly undulating beds, are *dip-joints* pointing between north and magnetic north; afterwards the beds have a steady dip about magnetic north; and the *dip-joints*, which abound, are exactly magnetic north and nearly vertical. At the same place are magnetic east and west joints (*strike-joints*), the planes of which are inclined magnetic south, 40°; that is to a point opposite to the dip of the beds, a very usual case. Not far from these beds are some masses of very coarse red sandstone, which seem to be subordinate to the earthy slates below this limestone.

the continual changes of mineral structure, no two distant sections can agree in their more minute details. The further range of the arenaceous series westward seems to be marked by the hard, irregularly bedded, gray quartzose rocks of Morleigh Down and Black Down, first noticed by Mr. De la Beche*.

2. Over the preceding group, and not separated from it by any well-defined limit, is expanded a slate formation of vast thickness. Soft glossy chloritic slates prevail, and alternate with arenaceous bands, and near Redlop Cove with a remarkable ferruginous whet-slate. Near Stoke there are some beds of flaky or semiconcretionary structure, like many beds associated with contemporaneous porphyries in Wales and Cumberland. Here, however, we saw no traces of trappean rocks. A little south of Stoke are some very fine beds of chloritic slate, exhibiting those wavy lines among the laminæ, which produce what we have called a *false stripe*; but there were no examples of an oblique slaty cleavage. For a considerable way north of Street the dip is reversed to N.N.W., but soon after recovers, and dips about magnetic south at a great angle. No calcareous beds fit for use are found in this series; but near Slapton it is overlaid by horizontal masses of new red conglomerate, which has been burnt for lime.

Near Torcross the dip is reversed to the north; and in a cliff to the south of it is a gray, greenish gray, and blue slate, with many quartz veins, generally parallel to the beds, but continually thinning out and running into filamentous veins. With these beds we found some long, flat, calcareous concretions: but we did not observe any organic remains, in this or any other part of the group. On the whole, the mineral phenomena, on this part of the coast, though differing in a thousand accidents, agree in all their essential circumstances with those exhibited by the corresponding group in Bigbury Bay.

3. For some way beyond the beds last described, the dip is nearly north at a great angle—on the average not less than 60°. A long flat region then conceals the relations of the strata; beyond which the crystalline group, commencing more than a mile south of Tor Cross, occupies the coast to the extremity of Start Point. The highest beds of this group are nearly perpendicular—they are then thrown into cortortions—and then for a considerable way along the southern cliff have a steady dip to the north at an angle of about 50°. Still further south they exhibit the same modifications of mineral structure that we remarked in the cliffs between Bolt Tail and Prawle Point.

At their northern limit they are certainly less crystalline than at their southern. Some of the beds contain many elongated concretions of quartz, spangled with flakes of mica or coated with chlorite, alternating with laminæ of dark chlorite slate; and associated with these are beds of very fine dark clay slate, of a structure intermediate between the slates of the second group and the crystalline slates of Start Point. It is obvious from what is stated, that there is no true passage between this and the preceding group; nor are the phenomena at the junction so instructive as those which occur at Hope Cove.

Such is the succession of rocks exhibited in transverse sections of South Devon; the whole ascending series being divided into four groups:

1. The slate-rocks bordering on Dartmoor, many parts of which are indurated and altered in structure by the action of the granite.

* In a traverse from Totness to Kingsbridge we crossed a series of red arenaceous slates which seemed to represent, under a different type, the great upper limestone and its associated red grit. Near Kingsbridge the beds are highly inclined and thrown into great undulations, caused perhaps by the same disturbing forces which produced the undulations near Avon mouth.

2. A great zone of slates, more or less calcareous, and with subordinate beds of limestone: the lower portion containing the Ashburton bands; the upper containing the great Plymouth and Tor Bay limestone. The upper portion also contains occasional beds of red slate and sandstone; which sometimes appear under the limestone, and sometimes seem to take its place along the lines of *strike*.

3. A great arenaceous group, containing many beds of red and variegated sandstone.

4. A group, with many courses of soft, glossy slate; sometimes indurated, and used for roofing-slate; alternating with coarse quartzose bands; without any subordinate beds of limestone, and apparently without fossils. These four groups complete the ascending series, and are, together, of an enormous thickness.

5. Lastly; a crystalline group of micaceous and chloritic slate, unlike any other formation in North or South Devon; not co-ordinate with any of the groups above described; probably of metamorphic structure, and due to some obscure axis of elevation, which has passed near the southern promontories of the county, and interrupted the succession of the regular ascending series.

Conclusions.

1. Comparing together the regions of North and South Devon above described, we find many points of resemblance, and some points in which their structure is remarkably contrasted. For example, trap rocks abound on some portions of the southern sections, but are never found in the northern. Again, in the northern region, a true transverse slaty cleavage is constantly developed among all the finer deposits; while in the southern, these cleavage planes are almost wanting, and nearly all the roofing slates are obtained from laminæ parallel to the stratification. Yet in South Devon, systems of parallel joints are as common as in North Devon. What physical conditions have led to this remarkable difference of structure we do not at present inquire.

2. Judging both from the mineral structure and organic remains of the two regions, we are justified in affirming that neither of them exhibits any very old class of slate rocks. For example, none of the groups, either of the northern or southern sections, are to be compared with the rocks of Snowdonia or the green slates of Cumberland; without including in our comparison the still lower group of Skiddaw Forest.

3. The preceding details show that there are many points of physical re-

semblance in the successive groups of North and South Devon ; and that there is a near resemblance in many of the fossils, especially the corals. Hence we should provisionally refer them to one system. But as there are no sections connecting them unequivocally with well-ascertained formations, a more exact comparison and place of the several groups must depend on a future examination of the fossils.

4. Attempting, however, provisionally to bring the groups of North and South Devon into direct comparison, we were first induced to compare the highest calcareous group of North Devon (No. 5.) with the great upper limestone of South Devon. The two formations in a part of their range are associated with red sandstone ; several of their fossils approach the carboniferous type, and some of their corals are specifically the same. But we were led to reject this hypothesis, chiefly because it left the great upper group of the South Devon slates (No. 4) entirely unaccounted for in North Devon.

5. The Ilfracombe calcareous slates very closely resemble (as above stated) some of the upper calcareous slates of Plymouth and Tor Bay. But if we rigidly identify the Ilfracombe limestone with the upper limestone of South Devon, we have the great red arenaceous group of Plymouth entirely unaccounted for in North Devon. On the other hand, the great red arenaceous group of North Devon (No. 2.) is, in its magnitude and general structure, almost identical with the great red arenaceous group over the Plymouth limestone. Notwithstanding our distrust of mere mineral characters, we seize on these groups as our best terms of comparison. On that hypothesis, the lower divisions of the South Devon section would be geologically lower than the lowest members of the North Devon section ; (which may be easily admitted when we regard the vast thickness of the descending series between Avon Mouth and Dartmoor (see Pl. LI., fig. 5 & 9.)) ; and the calcareous slates of Linton would be nearly on the parallel of the Plymouth limestone.

6. Not, however, to push these analogies too far, we would, in a general way, bring the great calcareous and arenaceous series, between the North Devon Foreland and Ilfracombe inclusive, into comparison with the arenaceous and calcareous groups on Plymouth Sound ; on which hypothesis the lower groups of South Devon are unrepresented in North Devon ; and the slate rocks south of the Ilfracombe limestone (group No. 4.) may be compared in a general way with the great upper slate group of South Devon.

We throw out these conclusions merely as provisional, and to be confirmed or invalidated by a more complete examination of the organic remains in the several groups.

Slate Rocks of Cornwall.

Before we proceed to describe the culmiferous series, we must notice the relations of the successive groups of North and South Devon, above described, to the slate rocks of Cornwall. The Plymouth limestone, as before stated, thins out to an edge in Whitesand Bay, being there represented by some inconsiderable beds of red calcareous sandstone and calcareous slate, with fragments of encrinital stems, and a few other organic remains. Nor does it again appear on the south side of Cornwall; being apparently cut off by the trending of the coast to the north-west of its line of *strike*. But the lower division of the fossiliferous slates of South Devon does pass into Cornwall, and gradually deflecting to the south-west, ranges through the cliffs at the mouth of the Looe River, through the hills near Talland, and thence by the hill above Lantivet Bay to the mouth of the Fowey river. The same calcareous slates reappear on the other side of the river, and are traced continuously through Greber Head, the south-eastern promontory of St. Austell Bay.

At all the above-named places fossils are abundant, though generally in the form of casts, and sometimes much obscured by cleavage. From the beds near Fowey we obtained several specimens of a large, deeply-ribbed spirifer, casts apparently of terebratulæ, stems of encrinites, and several fragments of corals. The same calcareous slates, sometimes passing into impure limestone, reappear near Veryan, and thence descend into the cliff towards the north end of Gerran's Bay—the last place where we found any traces of organic remains on the south coast.

At Gerran's Bay the strike deviates so much towards the south, that none of the calcareous slates pass through the cliffs that extend to St. Anthony's Head. In their further range, they again undergo a considerable flexure towards the west, which brings them nearly to the mouth of the Helford river; from which they strike, on the north side of the great plateau of serpentine, to the opposite coast of the Lizard district.

After what we had seen in South Devon, we were not surprised at discovering occasional traces of fossils along the lines above indicated. We were, however, astonished at the extraordinary number of organic remains in some parts of the country hitherto described as not fossiliferous. The calcareous slates are not confined to the line here indicated, but break out, on the eastern side of Cornwall, at considerable distances from the coast*.

* For example, there is limestone imbedded in slate about half a mile south of Hessenford; also at Catchfrench, a mile and a half above Hessenford; and at Coldrenick, a little east of Clicker Tor, &c., &c.

To the east of Looe, a section from the coast to the nearest granite exhibits on the whole a descending series; yet we do not think that any of the beds of such a section ought to be placed at a lower geological level than the lowest slaty group of South Devon.

In the cliffs west of Looe there are many fine green, chloritic slates, alternating with greenish quartzose beds, penetrated by quartz veins, which have a prevailing dip about S.E. by S. But at Ore Point is a striped rock, with numerous red and green bands, alternating with coarse green, quartzose beds, much penetrated by white quartz veins. The dip is reversed to a point about N.N.E., and is not less than 70° or 80°; and some of the beds have a true slaty cleavage inclined towards the same point, but at an angle of not more than 50°. The coarse striped beds, sometimes alternating with bands of nearly pure quartz (very instructive, from their mineral structure, and from a number of poor mineral veins nearly parallel to a series of north and south joints), are continued nearly with the same inclination to Polparrow. At the entrance of Polparrow Harbour, the coarser quartzose beds are overlaid by a beautiful rock, with a perfect transverse cleavage, producing a fine-striped slate. The beds dip north, at a great angle, while the cleavage planes dip also north, but at a much smaller angle. Examples of this kind occur very rarely in South Wales; and we never remarked a similar case in the North of England; for whatever be the inclination of the beds, the cleavage planes are generally inclined at a greater angle*.

As the same prevailing northern dip is continued to the mouth of the Fowey river, it is obvious that the beds above described are inferior to the fossiliferous group.

Similar indications of a northern dip are seen in a part of the coast section on the east side of St. Austell Bay. Commencing a section at Greber Head, and continuing it from thence through the head of St. Blazey Bay to the granite, we have the following order:

1. A series of quartzose and chloritic beds, continued to a cave under Combe Farm, with a prevailing dip towards the south. At that place there are large east and west joints, perhaps marking the presence of a fault; and beyond them the dip is reversed to magnetic north. The same phenomenon is also seen about a quarter of a mile south of Polkeris. 2. An ascending series, with a northern dip at a great angle, continued to Polmere Cove, where there appears to be a great break among the strata†. The fossiliferous slates are in the lower part of this group.

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* On the coast west of Padstow we found a still more remarkable example, viz. a calcareous slate, dipping unequivocally at an angle of 40°, intersected by true horizontal cleavage planes, producing a beautiful striped slate.

† Somewhere near the line of break, and probably connected with it, is a great channel of

3. A series of highly mineralized beds, with a southern dip, and extending to the granite. This division is traversed by some elvans, and numerous metalliferous veins; but there is no proof that it is of an older date than the second group: indeed, judging from the sections, it only seems to represent the upper part of that group reversed and mineralized by the granite, and by the causes, whatever they may have been, which produced the mineral veins.

The section from the Dodman point to the St. Austell granite, exhibits still more striking phenomena, in the following order:

1. A series of rocks dipping to the south-east, and extending from the Dodman to the cliffs south of Porthmellion. 2. A series of nearly similar rocks, extending to the cliffs south of Mevagissey, and exhibiting several anticlinal and synclinal lines—their most prevailing dip being, however, to the north side of the *strike*. 3. A long ascending series, continued close to the granite, in which there is a decidedly prevailing dip, and generally at a great angle, towards the north.

From the preceding facts, it appears that a line of elevation, nearly on the strike of the beds, has thrown the greater part of the *Killas* between Veryan Bay and Looe into an irregular trough; and that the crystalline, metalliferous slates skirting the south side of the St. Austell granite, instead of being among the oldest, are among the very newest stratified rocks of the south-east side of the county.

Nor does the mineral structure of the country throw any difficulty in the way of this conclusion. Many of the beds south-west of St. Austell are coarse, arenaceous, and sometimes of a red colour. Near Pentowan there is a series of coarse brown grits, almost resembling coal-measure sandstone; near Mevagissey and Porthmellion there is a coarse, dark-coloured slate, with specks of mica between the layers, much penetrated by quartz veins and alternating with arenaceous flagstone; further towards Gerran's Bay are thick courses of quartz rock closely resembling the masses of quartz rock in the great arenaceous group of South Devon; and in Gerran's Haven we meet with many very coarse arenaceous beds deeply impregnated with yellow hydrate of iron, alternating with bands of yellowish red and dark blue earthy schist. The ferruginous beds are carried to the west side of the promontory, where they are associated with masses more coarse and mechanical than those above described; and the quartz rock reappears in a rugged elevation south of Boswingran, and near Carhaise Bridge. We mention these facts to show the mechanical nature of many portions of this deposit. Other alternating portions have the usual characters of the finer chloritic slates of Cornwall.

manganese and iron, which ranges near the following places: Polmere, west side of Tywardreath Hill; East Polmere; Terras Hill, on the north side of Lostwithiel; and Restormel Ground;—the course being about N.N.E.

The same group on the north side of the Lizard serpentine also contains calcareous beds; not, however, passing into true beds of limestone; nor have organic remains been yet found associated with it. Among its upper beds are masses of coarse arenaceous rock, and beds of a very coarse red conglomerate; and south of Mawnan it contains a few very thin carbonaceous laminæ*.

Before our visit in 1836, Mr. De la Beche had completed his survey of the north side of Cornwall, and laid down his results in admirable detail on the sheets of the Ordnance map†. These he kindly communicated to us; so that in the few spots we visited to the south of Padstow, we only trod in his steps; on which account we avoid all details respecting this part of the north coast.

The section from the slate rocks north of the Lizard to the cliffs north of St. Ives Bay, appeared to us symmetrical. On both sides the *killas* is thrown off by the granite; and among the slaty and arenaceous beds which appear not far from Godrevey Island, are some cellular calcareous beds with ferruginous bands containing obscure traces of organic remains. One of the larger arenaceous masses reminded us of the Pennant stone of Bristol. We think we may safely consider these beds as very nearly the equivalents of a part of the group, north of the Lizard, which strikes into the coast near the mouth of the Helford river.

All the country round St. Agnes is so altered by the granite of Cligga point, by injected Elvan dykes, and by innumerable metalliferous veins, that we attempt not to define its exact geological relations—only remarking by the way, that after the facts stated above, we have no right to place the more crystalline slates of that district in any system lower than the groups above described.

Before our examination of the north coast, Mr. De la Beche had collected fossils from New Quay and other localities near the coast; also on the Padstow river, even so far up as the neighbourhood of Bodmin. We traced the calcareous slates with Encrinites, corals, and other fossils, through the cliffs north of Mawgan Porth; and the series is continued into Permizen Bay, west of Padstow, where we had seen the calcareous slates with fossils during a former visit to the county (1828). South of the Padstow river there are many irregular contortions; and the strike and dip undergo many changes, so that the fossiliferous slates are spread over a wide surface. It is obviously (after what we stated respecting the position of the beds south of St. Austell Moor) almost impossible to find any transverse section that will clear up the relations of the

* See Transactions of the Cambridge Philosophical Society, vol. i. p. 295.

† This map is not yet published; but a reduced copy of it appears in the lately published Report on the Geology of Devonshire and Cornwall. (1837.)

fossiliferous slates on the corresponding parts of the north and south coast. Provisionally, we identify the calcareous slates of New Quay, Padstow, &c., with the calcareous slates of Looe and Fowey. We see no reason whatever for considering one series older than the other; but for a final determination of the question we must look to a future examination of the fossils. The best fossils we possess from the coast near St. Columb Porth, we owe to the kindness of our friend Mr. Carlyon of Mawgan. Among them are Encrinites, two or three species of Orthoceratites, and several species of corals, &c.

The fossiliferous slates near Tintagel (first noticed many years since by Professor Buckland and Rev. J. J. Conybeare), cannot perhaps be connected by the direct evidence of sections with any of the preceding calcareous groups. The most remarkable fossil in these slates is a very large broad-ribbed *Spirifer*; and we found a similar fossil among the highly crystalline laminæ of the slates near Lesnewth, in the range of the slaty mass several miles further to the east. Calcareous slates, very nearly on the same line, after doubling (along with a great series of inferior beds) round the granite, are carried by a strike about E.S.E. to the quarries near Trenalt and South Petherwin. From the very numerous fossils in these quarries (among which are many large broad-ribbed Spirifers, Productæ, Terebratulæ, two or three species of Orthoceratites, many corals, Encrinites, &c.,) on the whole, nearly resembling those of the great upper limestone of South Devon; we should place these calcareous slates in an upper group of the great slaty series: and the conclusion is confirmed by the fact, that a section from South Petherwin to the granite, in a direction transverse to the strike (*i. e.* about S.S.W.), exhibits for five or six miles a regular descending series. These calcareous rocks are, in respect to the great overlying culm-trough, exactly in the same position with the calcareous slates of Barnstaple; but on this fact, considering the ambiguous relations of the base of the culm-measures to the rocks on which they rest, we do not at present build any inference.

From the preceding details we conclude, that whatever classification be given of the slate rocks of South Devon, must also include all, or nearly all, the slate rocks of Cornwall. They form one continuous system, the several parts of which admit no comparison as to age, except that which is sanctioned by the evidence of sections and fossils. The slates of Cornwall are, on the whole, more crystalline than the slates of South Devon,—a fact, however, on which no classification can be founded, as the upper groups, when near the granite, are as crystalline as the lowest. Again, many of the subordinate beds in Cornwall are as mechanical in structure as the very coarsest beds in South Devon.

The general absence of transverse slaty cleavage, in the parts of the counties we are comparing; the occasional appearance of that structure, especially among the calcareous portions; the occasional appearance of a second oblique cleavage plane; systems of dip-joints and strike-joints changing with the change of strike; and many other common accidents of structure (not to mention mineral veins, elvans, contemporaneous trappean rocks, &c. &c.), may also be considered collectively to bear out our previous conclusion. We have thus cleared the way for a description of the great overlying culm-measures of the central region of Devon.

Chap. IV.—*Culmiferous Series. Its relation to the other Formations, Structure, Fossils,* &c. (Plate LI. fig. 1, 2, 3, & 4.)

We have before stated that this series occupies a great trough, the axis of which ranges nearly east and west; and we have also indicated its north and south boundary in general terms. A formation may, however, be deposited in a trough, and yet the beds on its opposite sides may not exactly correspond. But in this instance there is no such ambiguity; for the bottom beds of the series have a peculiar mineral structure and are characterized by great beds of black calcareous shale and black limestone, with peculiar fossils, and these appear on both sides of the great trough.

That these lower beds rest on the highest group (No. 5.) of our northern section we have already given abundant proof. They are overlaid by an enormous thickness of contorted beds of shale and sandstone; and, by a reversal of the dip, are finally brought out again to the surface and seen resting on the slate rocks of Cornwall and Devon, and on the northern flank of Dartmoor. The trough is therefore symmetrical, and the true bottom beds of the whole series may be studied in detail either on its northern or southern boundary. We have, therefore, a most unequivocal proof that the culm-measures are newer than any of the stratified groups associated with them.

It may be contended, that there is a passage from the base of the culm-measures into the old slate rocks of Cornwall and Devon; and there may well be a mineralogical passage where both formations alternate with trap, or approach the granite, and so become metamorphic: but passages of structure proving a real continuity of deposit must always be difficult to establish among old slaty rocks, where similar beds recur at such enormous intervals. We must, however, allow that dark slaty beds and indurated shales occur in several places (for example, near South Petherwin; in a mining work on a moor

west of Lammerton ; and at the western end of Wheal Friendship * ;) at the base of the culm series, which it is extremely difficult to separate from the lower rocks ; but there is no ambiguity as to the order of superposition. In like manner, in North Devon, the beds of the highest group above described (No. 5,) pass regularly under the base of the culmiferous rocks, without the intervention of any conglomerate, or other appearance marking an interruption of deposit. But when one shaly mass rests on another, and is mechanically derived from it, we need not wonder at such a mineral passage. We have seen the old red sandstone on the coast of Caithness resting on granite and forming a most distinct mineral passage into it : and it was from overvaluing such apparent *passages*, that Macculloch was, for many years, led to regard the old red sandstone of the northern coasts of Scotland, as a part of his primary system. On the whole, therefore, we consider these supposed passages of little value in determining the age of the culm series, which we shall endeavour to discuss on other evidence †.

Lower Culm Measures.

The lower part of this series is made up of dark-coloured shale ; sandstone, sometimes coarse, but very rarely passing into a conglomerate ; siliceous flagstone ; and calcareous shale, here and there, containing subordinate beds of black limestone. The several members of the group are irregularly developed, and one part is expanded at the expense of the others ; but the calcareous portion is very constant, and its position is near the top of the lower division. Where the bottom shales rest on the earthy slates of the older groups, it is not always possible to determine the exact boundary of the two formations. This difficulty, however, such as it is, very seldom occurs ; as the inferior group abounds in fossils, while the culm slates are without fossils, and are also distinguished by their structure, being black and pyritous, and by occasional anthracitic stains between the laminæ.

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* The western end of Wheal Friendship, (an east and west copper vein,) near St. Mary Tavy, undoubtedly runs into the lower culm-measures ; the inferior and productive sinkings are probably in the older slates. On the other hand, Wheal Betsey, a north and south lead vein of the same mining field, is entirely in the lower culm shales and grits. We first thought an important inference might be drawn from this fact ; but we afterwards found several east and west copper veins, further north, in the undoubted culm-measures.

† We forbear to describe the confused junctions near Chudleigh ; where one of the great fossiliferous limestones of South Devon is surrounded by, and might seem to be imbedded in, the culmiferous rock. The phenomena are easily explained by the intervention of a fault. Neither do we purpose to describe in any detail the complicated junctions near Ugbrook Park, or an outlying basin of culm-measures south of Newton Bushel. All that side of Devon is extremely dislocated ; but the phenomena may be all explained, when the true order of superposition has been once settled on the evidence of uninterrupted sections.

These shales, in the ascending sections, frequently become semi-indurated; and in that condition are generally thin-bedded, and the separate beds are divided into innumerable prismatic masses by small transverse joints. In the softer varieties these masses are generally rhombohedral. Again, the indurated shales pass into rather thin-bedded, hard, siliceous bands, each of which becomes separated into cuboidal divisions; and the surfaces of the beds have what the workmen call a diced form, resulting from the intersection of parallel cross joints. This structure seems to be derived, in a great measure, from a tendency to a concretionary structure. These harder bands are often of a dark colour, and the partings are coated with earthy carbon, which stains the fingers. It is among the little transverse cracks and joints of the harder beds that a white earthy mineral greatly abounds. The white divisional planes are due sometimes to carbonate of lime; but through a considerable tract running near the base of the culm series (between Barnstaple and South Moulton) the white mineral is chiefly composed of earthy Wavellite; and occasionally the broken transverse joints exhibit the radiating crystals of that mineral in great perfection*. Still larger parallel joints, affecting the whole series, also occur; but these we are not at present describing. The same hard bands vary, however, greatly in colour, where the carbon is not present; and in several places they pass into a light gray, siliceous, brittle, jointed flagstone: and again, in some remarkable instances, they become almost white and porcellaneous, resembling a kind of china stone. Again the siliceous beds pass into a regular thick-bedded sandstone, resembling a coarse gray-wacké, or a grit of the coal measures: these latter varieties are, however, on the northern boundary (from which our present descriptions are chiefly taken) to be considered as the exception rather than the rule, and as subordinate to the carbonaceous shales and flagstones.

The beds forming the base of the culm series are somewhat differently developed on the southern boundary, in their range from the Cornish coast towards Dartmoor. We first meet with a highly carbonaceous and pyritous shale, dipping at a great angle from the chloritic and fossiliferous slate group of Tintagel. These alternate with coarse quartzose bands, sometimes thickly bedded, and resembling coarse beds of gray-wacké. The whole system is much intersected by joints, and traversed by large quartz veins†; and has so much the look of an old rock, that it has always been regarded as a regular part of the old slate series of Cornwall. The mineral character, however, as well as the superposition, is sufficiently distinct; and in several places (for example, on the north side of Boscastle) the coarser bands resemble a coal grit, are stained with carbon, and contain many very thin laminæ of that substance‡. Some of the shales are also calcareous, and contain masses of a variety of rottenstone, like that in the limestone shales of Derbyshire; but none of them contain any fossils resembling those of the older Tintagel slates. Among the higher beds of the series, we have a great development of black, semi-indurated shales; but no true bands of black limestone; and the whole group is violently contorted.

Following this bottom group to the east, along the line of *strike*, we still find the dark lower shales more or less carbonaceous, and with traces of bright anthracitic laminæ; and here and there (though rarely) with obscure traces of vegetable fossils§. And along the same line, further

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* The same mineral occurs among the indurated coal shales of South Wales.

† These veins are sometimes several feet in thickness. They usually run parallel to the beds for some way, and then come to an edge, or break off into small strings, ramifying through the neighbouring beds in all directions.

‡ These beds, or some resembling them near Boscastle, were first described by Dr. Boase, in the Transactions of the Geological Society of Cornwall, vol. iv. p. 426.

§ The descriptions of the preceding paragraph are taken from the lower culm beds near Bos-

east, the siliceous beds become so much expanded as greatly to predominate over the rest, and to give a character to the features of the country. Thus we cross, on the road towards Launceston, great tracts of arid soil resting on gray gritstone, which lies bleaching on the surface, and reminds us of the sterile ridges of a millstone grit country.

Partly in consequence of a thickening of this bottom series, and partly in consequence of a deviation in the strike towards the south, this remarkable deposit of gritstone is carried to the south of Bren Tor; and from thence, deviating considerably towards the north, and skirting the mining-field of St. Mary Tavy, passes into the high ridge of Black Down, and abuts against Dartmoor. Further towards the north-east, all the bottom grits and shales of the culmiferous system come up to the granite in succession, as may be seen in a traverse from Oakhampton to Tavistock; and the higher beds of the group then sweep round the northern promontory of the granite.

In this part of their course they are greatly altered in structure, and have even been mistaken for primary rocks. Their changes in structure are, however, due to two causes. 1st. They alternate with many beds of trap, and have their texture greatly changed in consequence. But surely no one will now contend that, on this account, they ought to be cut off from the other culm measures on their *strike*. 2ndly. When near the granite, the whole system becomes highly metamorphic. Should any one contend that the hard crystalline series between the coarse culm measures south of Oakhampton and the granite of Dartmoor, belong to a distinct group; we may reply, that the hypothesis is contradicted by the strike of the beds, and, above all, by the existence of beds of indurated black shale passing into Lydian stone, and black culmiferous limestone, (incontestably a portion of the true lower culm group, not yet described,) which pass through the heart of this altered group. And we might add, that, in the accidents of stratification, and in the existence of fine seams of Wavellite in the joints of the black indurated shales, we have additional analogies confirming our statement.

The complete demonstration of the general correctness of our views is, however, to be sought on the flanks of the granite hills to the south-west of Oakhampton. A traverse in that direction shows us the successive members of the group we are describing, as they range towards the granite one after another; and each, as it approaches the central rock, is found to undergo an appropriate change. Thus the dark shales put on the form of Lydian stone, and sometimes of compact felspar; and the quartzose bands, under the same conditions, are converted into a hard crystalline quartz rock. Close to the granite, the changes are more complete; the masses become utterly metamorphic, and put on the form of white compact felspar, micaceous crystalline slate,

castle. In their eastern prolongation, the pyritous shales near the bottom of the series become, in some instances, much indurated, and in a quarry about a mile from Launceston, on the South Petherwin road, are used for roofing slate. They contain vegetable impressions, and are of very bad quality, being injured by disseminated pyrites. The slate of Yeolm bridge (about two miles north of Launceston) is of much better quality, being derived from much harder beds, with a transverse cleavage plane, producing a smooth striped slate. The rock may, perhaps, be indurated by the neighbouring trap, which does not, however, appear in the quarries. It contains some organic remains, and is in a much higher part of the series which we are describing than the indurated pyritous shales above noticed.

gneiss, &c. &c. Nor is this all. The granite sends out veins into the altered beds, of which we found an example, not merely in the metamorphic beds of contact, but in a black, indurated shale, at a considerable distance from the junction, in one of the ravines south-west of Oakhampton. Moreover, there is an Elvan dyke (precisely like the Cornish Elvan) still further north, in the central portion of the culm measures, far above the group now under notice*.

Phenomena like these, where cause and effect are so clearly brought together, are of no small interest. The metamorphic group is one of the most instructive we have ever examined, inasmuch as we can trace it through all its gradations: and the facts we have stated prove to demonstration, that the granite is not older than the stratified series. And that it is not contemporaneous with the altered group, which is made up of a long series of mechanical deposits, is too obvious to require a proof. There remains, therefore, only one conclusion, (sanctioned by all the changes of position and structure, as well as by the protruded veins,) that the granite in mass is a rock of protrusion, and of a date posterior to the development of, at least, all the lower divisions of the culm measures.

We must now briefly describe the black shales and limestones which form the upper division of our present group, and are, indeed, its most characteristic and important members. These beds have so many characters in common, that the same descriptions will serve, with a few exceptions, for the black limestones both on the north and south side of the great culm trough; and on both lines it is extensively worked in a succession of large open quarries, in several of which are vertical sections more than 100 feet deep.

This upper division is regularly bedded, and essentially composed of black carbonaceous shale, traversed by numerous irregular white veins of calc-spar, and alternating with beds of black limestone. The limestone is also filled with white veins; and being of a rather earthy structure, is only distinguished from the calcareous shale by close inspection. Among the more calcareous bands some are fossiliferous, containing a great abundance of at least two genera of bivalve shells; one a *Posidonia*, the other of a genus not ascertained, but regarded, by those who have examined it, as a marine shell. In the same part of the series are *Goniatites* of at least two species, both of which are unquestionably marine, and (according to Professor Phillips) identical with *Goniatites* of the Yorkshire coal-field. And there is a negative fact also of great value. This culm limestone contains no fossils resembling those of the groups inferior to the culm series. The beds in question are therefore not more distinguished by their structure from all the calcareous strata of the inferior groups, than they are by their fossils. Yet the black culm-limestones and the calcareous slates of the older system, sometimes range almost side by side. This shows the absolute neces-

* This Elvan was first laid down by Mr. De la Beche.

sity (whatever may be its age) of mapping the whole culm series by a colour distinct from that of the older slates.

The group we have been describing is of great thickness, and the calcareous portions are several times repeated on the same section ; and not only in the shales, but also among the limestone bands, are thin laminæ of culm, but in no instance so thick as to be of economical use. It is difficult to estimate the whole thickness of this portion of the lower culm group, because the beds are repeated by contortions, which in some instances are so violent as to exhibit many salient and re-entering angles like those of a fortification agate. On the whole, however, the limestones and associated black shales plunge away from the older rocks, and gradually disappear under the upper culm-measures. On the south side of the culm-trough, the shales both above and below the black limestone are occasionally used for roofing slate. Thus, on the banks of the Lyd, near Coryton, there is a line of slate quarries apparently *under* the neighbouring range of the black calcareous rock, which, though excessively contorted on the small scale, (a single bed exhibiting five or six zig-zags in one escarpment,) dips on the whole about magnetic north ; and at Cory Park, immediately *over* the same contorted limestone, there is a very good striped slate derived from a true cleavage-plane. The beds dip magnetic north 35°, and are cut by fine vertical *dip-joints* : but the cleavage-planes dip magnetic south about 25° or 30°. Here, again, the cleavage-planes are less inclined than the beds—a phenomenon, perhaps, unknown in the north of England. We observed no beds of like quality in any part of the culmiferous rocks along their northern edge.

We think that the southern calcareous bands are in general thicker than the northern ; but the changes of mineral structure (excepting the metamorphic portion near the north end of Dartmoor) are more striking on the northern boundary. For example, near Bampton, there are several quarries, where the shales become indurated, have a conchoidal fracture, and a red colour, and sometimes pass into chert ; and near the same quarries the calcareous shales are associated with manganese, and the limestone bands are more crystalline, and become of a lighter colour. These localities also exhibit contortions of great complication ; but in that respect they are not anomalous.

Lastly, at Holcombe Rogus, we have a most extraordinary combination of sharp anticlinal ridges and contorted beds of limestone of great thickness, in which the black shale, which generally forms about three-fourths of the escarpments that are worked for lime, has almost disappeared, or at least become quite subordinate*.

* In nearly all the great quarries of black limestone, some of which are of great extent and grandeur, both on the north and south boundary of the culm system, not only are there considerable portions which are rejected as mere waste; but even in the richer portions with the true limestone bands, there is seldom more than a third or fourth part which is actually burnt for lime. The alternating bands of dark indurated shale (frequently riddled through in all directions by white veins) are used for flagstones or coping-stones. To prevent misapprehension, we may also state that the culm-limestone (though far more persistent than the limestone *junks* of the lower groups) often comes to an edge, or passes into mere calcareous shale. Hence quarries for economical use cannot be opened indifferently on every part of the *strike* ; and indeed along the coast of Cornwall the limestone has disappeared from the section.

We were at first doubtful with what rock we were to class the Holcombe Rogus limestone; but after a second visit in 1836, when we were better acquainted with all the varied characters of the lower culm-measures, we did not hesitate to place it in that part of the series. For it comes within the strike of the culm-measures; and it contains many beds resembling the limestone at Bampton (which is unquestionably a culm-limestone, and may be regarded as a connecting link between the ordinary black limestone and that of Holcombe Rogus). It rests on rotten pale-coloured and red shale, with bands resembling china stone, exactly like some beds on the line of the wavellite rock above described. Again, it alternates with bands of red unctuous shale, (which become indurated and pass into red flagstones,) and with bands of chert; and among its beds in one of the quarries is found a considerable portion of earthy manganese: in all which respects it is analogous to the Bampton limestone. Lastly, in the extreme paucity of its fossils, and their absence from the accompanying shale, as well as from its general structure, it is entirely unlike any of the limestones subordinate to the older group under the culm series*. Hence we think it certain that this limestone is a part of the lower culm group; differing from the other culm-limestones in being much more largely developed, at the expense of the shales and flagstones, and, as a natural consequence, differing also in being more pure and crystalline. It is repeated in six or seven distinct ranges of elevated or contorted beds and anticlinal ridges, within a space of three or four miles in length and breadth. In consequence of these replications, it is difficult to conjecture what is the whole number of its beds or their aggregate thickness†. In the grand anticlinal ridge (about a mile and a half south of Holcombe Rogus) there is a quarry at Canon Leigh that exposes a face of limestone rock about 150 feet thick: it is composed of a series of very thick, jointed, and shattered beds of a dark grayish blue colour, weathering like mountain-limestone, and alternating with thinner bands associated with hard red shale and chert. Among several of the subcrystalline beds we observed what may be considered a characteristic appearance in these quarries, viz. the dissemination of a series of distinct crystals of carbonate of lime through the more earthy base of the rock. It perhaps deserves remark, that

* We found a few fragments of encrinital stems in the limestone; but since the preceding description was written, Major Harding has found in it the characteristic *Posidonia*, which completes the evidence for our conclusion.

† The several ridges of limestone vary considerably in their *strike*; some ranging nearly east and west, others N.E. and S.W. Indeed, all the phenomena of this contorted district may be considered as instances of what has been before stated, respecting the great derangement of the older rocks, as they approach the plains of the new red sandstone.

among some contorted beds not far from the north end of the canal tunnel, we found some thick amorphous bands of dolomite.

We are aware of the extreme difficulty of conveying a distinct notion of the true aspect of a rock by mere verbal descriptions; but we may certainly say in general terms, that the great escarpments near Holcombe Rogus resemble mountain-limestone. And were we to seek for terms of comparison to describe the ordinary appearance of the black culm limestone (as seen between Bampton and Barnstaple, or along the south boundary of the culm-measures), we might compare it to the black beds of shale limestone in Derbyshire, or to some of the thin-bedded earthy limestones at the bottom of the carboniferous series in Craven; and more correctly still, to the darker varieties of the Irish *calp*. But we distinctly wish it to be understood, that we use these terms merely as descriptive, and with no view of prejudging the question respecting the age of the lower culm group.

In consequence of the contortions in this group (more particularly in its upper calcareous shales) it is difficult to form any correct estimate of its average thickness: we think that on the whole it is much thicker on the southern than it is on the northern boundary of the great trough. On both sides of Launceston the group is chiefly increased by the great expansion of the lower grits: and were we to make a transverse section from the lower beds of the whole series on the south side of Bren Tor to the northern limit of the calcareous shales, we must pass, notwithstanding the contortions, through an ascending series which cannot be estimated at less than two or three thousand feet in thickness, and is we think considerably more*.

* To make the previous descriptions better understood, we subjoin the following section of the lower culm series where it is exhibited on the largest scale. The section commences about two miles north of Tavistock and ends with the culm limestone on the north side of the great west road —a distance of about eight miles. It exhibits the following ascending order:

1. Lower shales and grits, the latter of very great thickness.
2. Trap of Bren Tor, part of it recomposed and regularly bedded.
3. Thin-bedded jointed rock, here and there penetrated by manganese and by trap.
4. A more slaty culm shale, having two courses of roofing slate.
5. Black culm limestone, overlaid by roofing slate, and by indurated thin-bedded shale and siliceous bands much jointed,—penetrated irregularly by manganese.
6. The same series, repeated over again (by a flexure and a fault) on the north side of Lewwater.
7. Upper limestone, and commencement of the higher division of the culm-series.

It is possible that the upper limestone may be only a repetition of the lower by a second great *fault*. The country is ill-exposed; but there is nothing in its form or in the dips of the beds to indicate such a *fault*. The thickness from the bottom shales to the first range of black limestone is, we believe, much greater than what is stated in the text. (See Pl. LI., fig. 7.)

Upper Culm-Measures.

This group, essentially composed of sandstone and indurated shale, is expanded through all the undescribed portions of the great culm trough, and indeed occupies nine-tenths of its whole surface. It is of very great, but unascertained, thickness; being perpetually interrupted, coiled upon itself, and repeated over again, by violent contortions, forming an incredible number of anticlinal and synclinal lines, ranging nearly east and west with the strike of the beds*. No words can exaggerate the number and violence of these contortions—sometimes in regular undulating curves—sometimes in curves broken at their points of contrary flexure, and exhibiting a succession of cusps, like regular pointed arches—sometimes, though more rarely, thrown into salient and re-entering angles, generally of local extent and only affecting particular beds. Indeed, we have some examples of such angles in thick beds of shale, where the massy sandstones, above and below them, are not at all contorted†.

These contortions become less violent as we approach the lower groups on the southern and northern outskirts of the formation. Thus, on leaving the lower group near Oakhampton and making a traverse towards the north, we cross, for some miles, a great ascending series of the upper culm group, in which the prevailing dip is north, and in which there are comparatively few undulations. And in like manner, in a traverse from the northern boundary (for example along either of the roads from Barnstaple to Bideford), we have a great ascending series of beds, and a prevailing dip to the south. Hence, though it be impossible to ascertain the whole thickness of the group, we are sure that it is very great; and respecting the general order of superposition we find no difficulty. Whatever may be the age of the upper culm series, it is uncontestably the highest group of our general north and south sections‡.

We have stated that the essential components of this group are sandstone and shale; sometimes exhibited in numerous thin bands, sometimes in thick well-defined masses. The sandstones are generally close grained, and full of irregular joints; and are coated over with ferruginous stains,

* Near the eastern boundary of the formation (as has been already stated) these lines are more irregular in their direction; and, as might be expected, there are many subordinate tracts (generally, however, of small extent) where the beds are in inextricable confusion, and their *strike* is irreducible to any system.

† A curious example of this kind (noticed in Mr. Greenough's map,) occurs at Mill Hook, on the coast of Cornwall.

‡ See the sections from the Foreland to Dartmoor, and from Marwood to South Petherwin. (Pl. LI., figs. 1 & 2.)

exactly like bands of coal-grit. They are often gray, or brownish gray, and sometimes greenish gray, and are occasionally stained by red hæmatitic joints. And on the north side of Portledge Bay there is a series of sandstones and alternating shales of a deep red colour, which produce a distinct feature in the county, and may be traced for many miles along the strike, all the way preserving their peculiar mineral character.

The system is traversed here and there by quartz veins, sometimes passing in well-defined transverse lines, and sometimes reticulated through the whole mass of the rock. Many of the thick gray beds exhibit, on their weathered and water-worn surfaces in the sea cliff, a number of spherical light-coloured spots, indicating an approach to a concretionary structure. Specks of silvery mica are disseminated through many of the masses, on lines parallel to the bedding; and sometimes the mineral becomes so abundant that the rock has a flaggy structure, and resembles the coarse flagstone, so commonly used as a roofing slate in all our coal countries. The thinner beds alternate with, and pass into, a laminated arenaceous shale, with fine ripple marks at the partings. This last variety is sometimes (for example, on the coast of Bideford Bay, south of the Popple Bank,) continued through a thickness of many hundred feet; with hardly an interruption from the thick hard coarser beds of sandstone.

The shales vary from a sandy, micaceous, laminated flagstone, to a soft slate-clay, not distinguishable from a common shale of our true coal-measures. Sometimes they exfoliate into innumerable thin flakes; sometimes their weathered surfaces decompose into thin transverse prismatic masses, like the forms of starch. Many of them are pyritous, and are coated superficially with a white efflorescence or with brown ferruginous stains, precisely in these respects resembling coal shales. Among them are, here and there, dark carbonaceous bands which stain the fingers, generally in the form of mere laminæ; and near the junction of the shales with the harder flagstones, the dark laminæ often contain innumerable obscure vegetable impressions much discoloured by decomposing pyrites: occasionally, but more rarely, the dark shales contain glossy plates, having the lustre of plumbago, in which case they seem to pass into the state of culm. The best examples of these glossy plates are, however, seen in the shales of the lower culm group already described.

Impressions of plants are also found occasionally among the strong beds of sandstone; for example, in a quarry by the road-side about half-way between Barnstaple and Bideford*. In Ugbrook Park, near Chudleigh, there is a large development of culm sandstone as coarse as millstone grit, and passing into a conglomerate form; and over it are some beds of more thin-bedded, gray sandstone, not to be distinguished from a coal-measure sandstone, and containing very fine vegetable impressions, among which are well-marked Calamites. Indeed, through the whole of the upper group we are describing, vegetable impressions, though rarely so perfect as to give anything like specific characters, are extremely abundant.

Nodules of clay-ironstone are occasionally associated with the hard beds of sandstone; and sometimes they occur in beds, or rows, subordinate to the shaly bands. Among the accidental beds we may also notice calcareous shale passing into thin, impure bands of limestone, of which we saw an example near Hatherleigh†. All the beds above described are intersected by nume-

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* These gritstones may be called the *upper culm grits*, to distinguish them from the coarse grits of the lower division, in which we never discovered any Calamites. The upper grits are diffused through the whole upper division of the series, but perhaps abound most in the part that first succeeds the black limestone and shale.

† See the section from the Foreland to the granite of Dartmoor. (Pl. LI., fig. 1.) Similar

rous open joints, which in the coarser contorted beds are very irregular in their directions. But when the beds have a finer flaggy or shaly structure, the joints often become parallel, (especially in a direction nearly transverse to the strike) so as to separate the strata into prismatic masses.

The description above given of the culm-measures, is copied from memoranda made on the spot during our traverses through the formation. The prevailing characters of the formation are the same throughout, and with very few exceptions (which occur chiefly in the metamorphic portions), there is no difficulty in identifying it by its mineral characters alone. Its dark colour, the imperfect induration of the shale beds, the absence of slaty cleavage*, the coarse mechanical nature of the bands of sandstone, and the perpetually recurring contortions, enabled us to follow it throughout, to trace it round the N.E. flank of Dartmoor, and to make out the boundaries of certain outliers of it which occur near Newton Bushel. And when we combine with these characters the very frequent occurrence of vegetable fossils, we can seldom fail to make out the place and limits of the deposit among the older rocks of Devonshire.

There are other appearances in the very external aspect of the county to help us in determining the superficial extent of the culm series. The continued undulations of the whole region, where the contorted strata are expanded in a numberless succession of ridges, prolonged east and west like the anticlinal and synclinal lines of the inferior strata—the great extent of a yellow, sterile, and, we believe, pyritous clay, producing a cold, fruitless soil, exactly like that among the cold lands of our coal-measures†;—these characters often enable us, at a glance, to separate this formation from all the other deposits of the country.

Such are the prevailing characters of the two groups into which we have divided the culmiferous series; and such are the prevailing characters of the subordinate parts: and whatever may be their place in the general scale of British formations, this at least is certain,—that they are more recent than any of the other deposits, described in our transverse section, from the north to the south coast of Devon, and that they are overlaid by no rocks older than the

thin impure beds of limestone are found in several other places in the upper culm-measures. We are indebted to Mr. Austen for the following localities; viz. Chittlehampton, Romansleigh, King's Nympton and Bishop's Nympton, High Bickington, Horridge Moor, Instow, and Harwood.

* We have already described some exceptions to this rule in the shales of the lower group, east of Launceston; and similar exceptions occur in the metamorphic portions near Oakhampton.

† The sulphate of iron in the pyritous clays, where it meets with the roots of the oak, sometimes produces streams of natural ink, which discolour the deep cuttings of the soil, by the sides of the cross roads, to a considerable distance.

new red sandstone. So far we may state our grounds of conviction with unlimited confidence. Neither can they be classed with any of the other formations with which they are associated; as has, we think, been sufficiently proved in the previous portions of this paper. But in approaching the definite question—what is the exact epoch of the culm-measures?—we must fortify ourselves with some more specific evidence, which might indeed have been incorporated in the preceding general description, but which we have deferred to this place, in order that the facts it offers might appear in a more prominent form.

In addition, then, to the thin carbonaceous bands above noticed, there are, on the coast near Bideford, and extending from thence along the line of *strike* far into the interior of the county, some much thicker bands of culm, which have for many years been extensively worked. This fact was known by all persons who had examined the structure of North Devon; but we believe Mr. De la Beche was the first who made the Society acquainted with vegetable fossils, derived from these localities, sufficiently well marked to admit of a botanical description or comparison with the vegetable fossils of other formations.

Near the coast, the culm appears to have been worked on two lines very near each other; and on the north side of the culm beds is a very ferruginous grit in a highly-inclined position, and exactly parallel to the culmiferous shales*. When we visited the coast during the past summer (1836), they were extracting no culm for domestic use; but were working one pit, sunk, we believe, on the southern line of culm, for the sake of a highly carbonaceous and unctuous shale, which runs side by side with a thin band of pure culm, and is extensively sold as a black pigment.

The same culm beds have been traced eastward through the S.W. end of Bideford; and they were formerly much worked there in pits which are now deserted. About two miles to the east of the town there have also been very extensive works, which were partially re-opened last summer (1836), but with what success we have not heard. At that place, there are three highly-inclined beds of culm, designated by the names of south, middle, and north veins,—all of which dip south.

The *south vein*, or paint vein, is about three feet wide, and on its north side is a carbonaceous shale, used for paint. The whole bed is very impure, and contains little good culm fit for burning.

The *middle vein* is fifteen fathoms north of the former, and is about four feet thick on the average, but expands, in some places, to twenty feet, and in others is pinched out to a few inches,

* See Pl. LI., fig. 3.

the culm appearing here (precisely as in the contorted culmiferous strata of Pembrokeshire) in large spheroidal masses, much shattered and broken, as if they had undergone irregular compression among the contorted beds of sandstone. Some parts of this bed are very good for domestic use.

The *north vein* is forty fathoms north of the preceding. It is two feet wide on the average, and is liable to similar variations with the middle vein; and it has been much worked, though it is not of so good a quality as the former.

The pit we examined was sinking on the south side of the *middle vein*. The sole of all the culm beds is sandstone, rather close-grained, and in some places ferruginous; and the roof is composed of indurated shale (called *shillat*): but in the *middle vein* the shale roof sometimes passes into a gray micaceous flagstone, mixed and stained with glossy culm, and is exactly like a grit of the culm measures of Pembrokeshire. Plants are found in all these overlying shales; and carbonaceous impressions (sometimes with distinct traces of vegetable structure) occur also in the sandstones, both of this and the other localities.

These mineral details are copied, word for word, from our memorandums made on the spot, and are enough for our present purpose*. It only remains for us to give a list of the fossil plants, many of which are now before the Society.

PLANTS IN THE CULM STRATA OF DEVON, DETERMINED BY PROFESSOR LINDLEY.

DEVONSHIRE.	OTHER LOCALITIES.
Asterophyllites foliosa. Foss. Flora, Pl. 25. f. 1.	Jarrow Colliery, Newcastle-on-Tyne.
Calamites undulatus. Ad. Brongniart, Veg. Foss., Pl. 17, fig. 1, 4.	Low Moor, Yorkshire. Radnitz, Bohemia, &c.
C———. Species resembling *C. arenaceus*, Ad. Brongn.	
Cyperites bicarinata. Foss.Flora, Pl. 43. f. 1, 2.	Upper coal measures, Salop.
Neuropteris gigantea. Sternb. Tent. Flor. Primord. Tab. 22. Ad. Brong., Pl. 69. Foss. Flora, Pl. 52. (*Osmunda gigantea*, Sternberg Flor. der Vorw. *Filicites linguarius*, Schloth. Flor. der Vorw., Tab. 11. fig. 23.)	One of the most abundant coal plants in Germany and in England.
Neuropteris cordata. Ad. Brongn., Pl. 64. fig. 5. Foss. Flora, Pl. 41.	Upper coal measures, Salop, and common in the English and French coal-fields.

* There are many old deserted works much further towards the east. The attempts to work the culm beds near their eastern limit have hitherto failed to reward the adventurers with any profit. The last attempt was made upon a very thin bed in the hills about two miles north-west of Bradwick.

DEVONSHIRE.	OTHER LOCALITIES.
Pecopteris lonchitica. Foss. Flora, Pl. 153. *P. blechnoides & lonchitica.* Ad. Brongn., Pl. 84. f. 1–7. Scheuchzer. Herb. Diluv., p. 74. *Filicites lonchiticus.* Schloth. Flor. der Vorw., Tab. 11. f. 32. *Alethopteris lonchitidis et A. vulgatior.* Sternb. Flor. der Vorw., Tab. 55. This species is perhaps the *most abundant* of the *Bideford Plants*.	Upper coal measures, Salop. "One of the commonest of the plants of the coal formation, as the opposite list of authorities indicates, occurring in great numbers in a variety of mines in France, Bohemia, Silesia, and England; very abundant in the culm measures of Pembroke."
Pecopteris muricata. Ad. Brong. Veg. Foss., Pl. 95. fig. 3 and 4.	Coal Mines of Argin, near Valenciennes, and near Wittin, Saxony.
Poacites cocoina. Foss. Flora, Pl. 142 B.	Coalbrook Dale and other Salopian coal-fields, and also in the Lancashire coal near Bolton; a very remarkable species of palm. (See Lindley and Hutton.)

In addition to these plants clearly exhibiting the characters on which fossil species are determined, there is a considerable quantity of impressions of coarse, sedge-like, or grassy vegetables, which, though not easily defined, are apparently identical with fragments very common in the Pembrokeshire coal-field. We would here also call attention to the fact, that every species of these Devon plants which is well preserved has at once been identified by Professor Lindley with well-known and previously-published vegetable forms of the true carboniferous era. Among these, the *Pecopteris lonchitica* and *Neuropteris cordata* may safely be cited as among the most common and characteristic plants of nearly *all the European coal-fields.*

On the whole, considering that the culmiferous rocks of Devon form a distinct group, with a peculiar mineral type (unlike the older groups, but nearly resembling the culmiferous beds of Pembrokeshire)—that they overlie all the other groups, and are overlaid by no rock newer than the new red sandstone—that, notwithstanding the paucity of fossils in the black limestone (in which respect it resembles the *calp* of Ireland), there are in it one or two species not separable from known mountain-limestone fossils,—and, finally, that the *flora* of the upper culms, as far as it has been ascertained, agrees specifically with the known *flora* of the carboniferous period; we think we have strong direct evidence to establish our position, "that the upper culm strata of Devon are the geological equivalents of the ordinary British coal-fields." Our conclusion is drawn from direct evidence, and can only be assailed by direct conflicting evidence, of which we have not yet discovered any trace.

Besides the plants of the strata which we refer to the true carboniferous series, other fossil vegetables have been discovered since our first visit to Devonshire, in the sandstone beds of Sloly quarries, north of Barnstaple, which are near the base of the fifth group of our North Devon section; and, therefore, far below the culmiferous series.

This discovery was first communicated to us by Major Harding, of Ilfra-

combe, to whose exertions we have already alluded*. He forwarded to us, several months since, a few stems of plants from Sloly quarries, accompanied by casts of shells from the sandstone rocks of Marwood; and had this memoir not been unavoidably retarded, we should have announced his discovery at the commencement of the year. Meanwhile, however, the Rev. D. Williams having revisited the same locality, has procured a more abundant and perfect supply of fossil plants from it, which he has sent to the Geological Society to illustrate a memoir of his own; and he has kindly permitted us to examine them. On referring these plants to Professor Lindley, we were favoured by him with the following opinion:—

"I am of opinion that these remains are not susceptible of *specific* identification; you can only approximate to their determination: 1, 2, 3, 4, 5, are probably portions of the same species, and are undoubtedly a *Stigmaria* or a *Lepidodendron*; the absence of all trace of a hollow axis, and the similarity of their surface to that of decorticated *Lepidodendra*, induce me to decide for the latter.

6. Is probably another portion of the same plant; but this is uncertain.

7. Is more analogous to some states of *Sternbergia* than to any other fossil I am acquainted with. It agrees with that genus remarkably in the intermixture of strong longitudinal fibres and coarse cellular substance; and at all events may be safely considered as the remains of some arborescent *Moncotyledon*.

8. Is so imperfect that it is hardly safe to refer it to Calamites; and yet the apparent obliquity of the only articulation that the specimen exhibits, is so much that of *Calamites Voltzii* of Ad. Brongniart, as to render it probable that it may belong even to that species.

9. Has on one side the evident impression of a *Lepidodendron*; on the other side it is striated like *Calamites arenaceus*? perhaps it was the latter moulded on one side upon the stem of the former.

10. Was possibly a portion of No. 7, with the cortical integument less decayed; on the lower left hand side, quite at the edge, is a small part of the surface, which will nearly match a part of No. 7.

If these conjectures are correct, the whole of the specimens are referable to *genera* of the coal measures; but whether they are specifically the same, I cannot say."

Such are the remarks of Professor Lindley on the fossil plants of Sloly quarries; and we contend that they oppose no real difficulties to our previous conclusions respecting the age of the culm beds. Should true coal plants be discovered in the lower group (North Devon, section No. 1), they would not, we think, upset conclusions founded on so much direct evidence. They would, however, prove one of two things—either that such plants had an unusually wide geological range; or that the group below the culm measures was of a more recent date than we first imagined; and formed (as has indeed been

* *Supra*, p. 648.

supposed from the evidence of sections) a true passage into the lower division of the overlying trough. The only fact which could materially disturb our proposed classification, would be the discovery of a series of plants among the culm beds, unlike the fossil *flora* of the true coal-fields, and resembling the fossil *flora* of some well-ascertained lower formation. But such a series never has been, and we believe never will be, discovered in Devonshire*.

The culm series, considered as a whole, cannot be properly classed with the inferior groups ; as it has a distinct position, a different structure, and a peculiar suit of organic fossils, animal as well as vegetable. It must therefore be represented, hereafter, on our geological maps by, at least, one distinct colour. So far we conclude with perfect confidence.

The enormous development of this series, the absence of the old red sandstone and mountain-limestone in their more usual form, and the fine slate rocks in some parts of the lower culm group, may seem to make its geological base somewhat doubtful. Again, the parallelism of position of the lower group and the formations on which it rests (both on the north and the south sides of the great trough), and its apparent passage into them, tend to increase this doubt. Provisionally, then, and as a measure of caution, we are willing to place the base line of the culm series in a geological position, not yet perfectly defined. But, we repeat, no such ambiguity attaches to the upper part of the culm series; as all the vegetable fossils derived from it, are identical with published species, before obtained, from the true coal measures overlying the mill-stone grit.

Again, as the members of the whole culmiferous series (including both the upper and lower divisions) appear to have originated in one uninterrupted succession of operations, have a nearly common type, and partake of the same accidents, we certainly think that they must all be classed together. And if this reasoning be correct, the lower groups of black shale and limestone (whatever be the supposed ambiguity of the base line) must also be classed with the true carboniferous system. In its structure and in the paucity of its organic remains, it resembles the *calp*, or argillaceous limestone, at the base of the carboniferous system of Ireland ; and the specific characters of its fossils, as far as they go, do not invalidate but confirm the conclusion we have drawn.

* Some new facts have come to light (since the spring of 1837) connected with this subject, to which we refer in the second part of this communication.

Chap. V.—*Granite of Dartmoor; its Structure and Relations to the Stratified Rocks, &c.*

It only remains for us to describe in a few words, the Dartmoor granite and the phenomena presented at its junction with the other stratified formations:—

1st. It presents the large porphyritic structure, the contemporaneous crystalline portions, and veins of schorl; the portions liable to decomposition from the disappearance of the alkaline constituent of the felspar; the hemitrope crystals of albite; and in short, almost all the other well-known accidents of structure, which have so often been remarked in the Cornish granite. Indeed, there can be no doubt, that, from Dartmoor to Land's End, all the larger protuberances of granite belong to one common system of formation; and they present the like phenomena at their junction with the stratified rocks.

2nd. There are other accidents of structure, common to the granite of Devonshire and Cornwall, which we may also notice—more especially the joints. Every one who had written on the granite of these counties, had noticed the occasional prismatic, or cuboidal, forms of the rock; and Dr. McCulloch endeavoured to account for these phenomena on the hypothesis of interfering spheroidal concretions. Since that time, Mr. Fox and Mr. Enys have shown, that two leading sets of these joints are nearly perpendicular to the horizon; and have (in the western parts of Cornwall) given bearings with respect to the points of the compass,—one set being nearly magnetic N. and S., and the other nearly magnetic E. and W.; while a third set are nearly horizontal*. Nor did their remarks end here; for they showed, by the peculiarities of its cleavage, and the prevalent arrangement of the larger felspar crystals, that these joints were due to a crystalline arrangement affecting the whole mass of the granite. These arrangements, however, fail on the outskirts of the granite; more especially in the deviation of the tabular joints, which, in such cases, often assume a kind of dome-like shape, conforming rudely to the actual surface of the country. Dr. Boase has also dwelt largely on these subjects, and shown that many of the accidents of structure, especially many master-joints, are common to the granite and the rocks in contact with it†.

Now all these important peculiarities of structure (first observed in the western parts of Cornwall) are equally true of the granite and contiguous rocks of Dartmoor‡.

* See Phil. Mag. May 1833.

† See various Memoirs by Dr. Boase in the Transactions of the Royal Geological Society of Cornwall.

‡ From the mean of our observations we should place the bearing of the principal north and

The leading system of joints is the same with that observed in Cornwall, whether we examine the granite or the altered rocks that are close to it. This remark applies to the culm measures, as well as to the older slates; and the fact seems to show, that the joints (common to the granite and contiguous slates) must be contemporaneous. But it by no means follows from this conclusion, that we should thence infer, as has been done by Dr. Boase, that the granite and the contiguous slate rocks are also contemporaneous. Such a conclusion is manifestly contradicted by the facts stated in the preceding parts of our paper.

3rd. Granite veins, passing from the central mass into the superimposed stratified rocks, are found on all sides of Dartmoor. We have seen them above Ivy Bridge, injected among the oldest slates of Devonshire; and near Oakhampton, we have seen them in like manner, penetrating the culm measures: and they are finely exposed in the beautiful gorges of the Teign and the Dart, where those rivers descend from the granite to the culmiferous series. These examples, to which we could add many more, are sufficient for our purpose. Now these veins, taken in general, are mere prolongations of the central granite, inseparable from it, and contemporaneous with it; they cannot therefore (as the granite is one mass) be contemporaneous with stratified rocks of different ages. Consequently they are true veins of injection, and the granite was protruded at a time, posterior to all the other stratified systems.

Again, the beds and masses of trap, associated with the stratified rocks, do not penetrate the granite (as they do in the Isle of Arran and many other places) but are uniformly cut off by it. This seems to prove that the injected trappean masses obtained their present position among the slates before the granite existed in its present form; and the same conclusion is still more certain when applied to the stratified, or recomposed, trappean rocks which alternate with the slates.

4th. The strata round Dartmoor are not all mantle-shaped. On the north-western and north-eastern sides of it, their *strike* is not much altered by the granite; and the successive beds may be said to abut against, rather than

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south joints about five degrees east of magnetic north. Mr. De la Beche, in his recently published *Report*, gives many accurate details connected with this subject, which on the whole confirm the statements first given by Mr. Enys and Mr. Fox. A person after reading these statements might perhaps be disappointed on commencing an examination of the granitic hills of Cornwall, and finding the joints often quite anomalous in their directions. For reasons already stated, such an examination must not begin on the outskirts of the granitic hills, and no mean directions can possibly be established, except on a large number of averages. (1839.)

mantle round the central rock : yet the ends of these abutting strata are perfectly metamorphic. This fact we think important, as it proves to demonstration, that these strata are, in the strictest sense, *metamorphic*, and do not belong, as has been supposed, to a system of deposits older than the less crystalline beds, which are further from the granite.

5th. There have been two distinct regions of elevation in the country above described ; one commencing in the great granitic mass of Dartmoor and extending into Cornwall,—the other, nearly parallel to, and not far from, the north coast of Devonshire. The compression of the central mass in North Devon, by the elevation and protrusion of the rocks on these two lines, may perhaps have been among the means which produced the contortions of the great culm-trough.

6th. Lastly, as a general conclusion from all the previous details, it appears that the rocks of Devon and Cornwall belong to three periods of formation. The oldest includes the various groups of slate rocks, and, at least, a part of the associated traps. The next includes the culm series, the upper division of which contains fossils identical with those in the upper division of the true coal measures. The granite belongs to the newest period ; but (on evidence not discussed in this paper) probably assumed its present position among the rocks above described, before the deposit of the new red sandstone.

On the Physical Structure of Devonshire, and on the Subdivisions and Geological Relations of its older stratified Deposits, &c.

[Read April 24th, 1839.]

PART II.

On the Classification of the older stratified Rocks of Devonshire and Cornwall, &c.

In a former communication we described the mineral structure, and the order of superposition, of the successive groups of rocks which are crossed by a section from the north, to the south coast of Devonshire; and by following the beds (along their line of *strike*) into Cornwall, we were enabled, within certain limits, to bring the *killas* (or slate rocks of that county) into comparison with some of the lower Devonian groups. In this way, we ascertained the existence of a great culmiferous trough, superior to all the other groups in North Devon, and distinguished from them both by its physical structure and its organic remains. Hence we concluded, that the culmiferous series must be represented, for the future, in our geological maps by a distinct and appropriate colour. We had stated the same conclusion, and on precisely the same evidence, at the meeting of the British Association in 1836. We further concluded, that, at least, all the upper portion of this series was of the age of the great coal-formations of England; inasmuch as all its vegetable fossils, as far as they were ascertained, agreed specifically with undoubted coal plants. To this conclusion we still adhere; and we regard the culmiferous rocks as forming a true geological horizon, to which either the ascending or descending series of deposits may be referred.

Again, in the arrangement of the several groups below the culm-trough, as they appear on the North Devon section, we have no modifications to suggest; and the very illustrations which were before suspended (1837), to explain the actual succession of the deposits, will serve our purpose at this moment.

Since our first notice of this section in 1836, Mr. De la Beche has examined the country in great detail; and his arrangement of the several fossiliferous groups, inferior to the lower culm beds, agrees with our own *. The

* There is one unimportant exception to this remark which we have noticed in our former paper (see p. 642, note). It fortunately does not affect the position of the fossiliferous groups, or any question connected with their classification.

same may, we believe, be said generally of the arrangement given by Mr. Williams. We shall, therefore, for the future, refer to the successive groups in the North Devon section with entire confidence. The only questions which can now arise, must refer to their age and classification,—not to their relative position.

To our four sections, illustrating the structure of South Devon, we make no material change or addition; with one exception, however, viz. the interpolation of a small band of culm measures between the Ashburton limestone and the granite—discovered by Mr. Austen since our visit in 1836, and represented (Pl. LI., fig. 8.) on his authority, as has indeed been already stated in a note to our former paper. Neither have we any material change to make in our comparison of the deposits of North and South Devon. Considered as a whole, we still think that they belong to one system of formation; and that the lowest group of South Devon is lower than the lowest group of North Devon. But as for our comparison of the subordinate groups (though still the best that we can offer), we only throw it out as provisional, being chiefly founded on mineralogical characters, and those perhaps not of a very conclusive kind.

Lastly, we have no change to make in our description of the fossiliferous groups of Cornwall. They are very nearly on a parallel with groups exhibited in the sections of North and South Devon; and the fossiliferous slates of both counties belong to one system. We do not encumber ourselves with any details respecting the more crystalline and (as we believe) *altered* slates; but we have, in our former paper, shown that they are not, merely on account of their structure, to be regarded as older than the calcareous and arenaceous deposits.

After these preliminary remarks we proceed (agreeably to a promise given in our former paper) to re-examine the classification of the respective groups inferior to the culm measures; and we begin by expressing our entire conviction that the true equivalents in the several disjointed sections can only be made out by zoological evidence.

We were at first led to the opinion, that the series of deposits we are describing, were to be placed below the Silurian system, partly from the resemblance of the highest group (No. 5 of the North Devon section) to the Caradoc sandstone; and perhaps still more from the mineral structure and slaty cleavage of many parts of the lower groups. At that time we had not sufficient boldness to adopt the only other alternative, and throw all the old slates of Devon, and the (supposed) primary slates of Cornwall, into the epoch

of the old red sandstone. We were aware, indeed, that several of the South Devon fossils conformed nearly, perhaps specifically, to the type of the carboniferous limestone. But on the other hand, no one was able to define the descending range of such organic forms; especially as it was asserted, that they *reappeared* in the south of Ireland, in beds alternating with true greywacké—or rocks supposed to be older than the old red sandstone. Hence we placed, *provisionally*, but with no satisfaction to ourselves, or confidence in our evidence, all the older fossil groups of Devon and Cornwall in that great but ill-defined interval that exists between the Caradoc sandstone and the older slates of North Wales. Since 1836 we have received repeated proofs of the insecurity of our first hypothesis. Thus, Mr. De la Beche (1837) exhibited fossil plants from the quarries of Marwood (Pl. LI., sec. 2.) one of which Professor Lindley identified with *Stigmaria ficoides*, a very common coal-plant; and near the same place we had ourselves found a *Bellerophon*, not to be distinguished from *B. lobatus* of the old red sandstone. Again, Mr. Lonsdale, after an extensive examination of the fossils of South Devon, had pronounced them, more than a year since, to form *a group intermediate between those of the Carboniferous and Silurian systems*, and hence he concluded that the fossiliferous rocks of South Devon were subordinate to the old red sandstone. This view could be effectually maintained only by one who knew the fossils of the Silurian system. The work in which those fossils are described, proves that the fossils of the Silurian and carboniferous systems are quite distinct. It also proves that the fossils of the old red sandstone of Herefordshire are of a peculiar type; and, at the same time, it points out a want of zoological continuity in the development of organic forms between the epochs of the carboniferous and Silurian deposits. There is, indeed, a true zoological transition between the highest group of the Silurian system and the lower part of the old red sandstone; but between the middle and upper groups of the old red sandstone and any part of the carboniferous limestone no such transition had been discovered. These facts were well known to Mr. Lonsdale, and hence his conclusion respecting the age of the South Devon limestone was based on incomparably better evidence than the mere specific resemblance of some of its fossils to those of the carboniferous limestone: for he contended, as above stated, that the organic remains of South Devon formed a connecting link between the carboniferous and Silurian fossils; and thus supplied that zoological continuity which before had been sought for, but never found.

But this is not the whole of the evidence by which we were gradually led

to distrust the views, we had first entertained respecting the age of the older stratified groups above described. For one of the authors, during the summer of 1838, re-examined a part of the great transverse section of Devonshire, and was more than ever convinced that, with some ambiguous exceptions, there was on each side of the great trough a true passage from the lower division of the culm-measures into the inferior fossiliferous group. Thus the section from Marwood across the culm series to the calcareous slates of South Petherwin seemed to be perfectly symmetrical (Pl. LI. fig. 2.), the lower beds of the culm-measures being repeated (as described in our previous paper) on both sides of the trough; from beneath which emerge on the respective sides, and in a regular uninterrupted sequence, the calcareous slates of Petherwin and Barnstaple. Now, if this view be correct, it follows, almost inevitably, from our own evidence, that the calcareous slates in question must be very near the upper limit of the old red sandstone; and this conclusion being once admitted, we should have little difficulty in classing, not merely the calcareous rocks of North Devon, but also the fossiliferous slates of South Devon and Cornwall, with the old red sandstone.

To the preceding facts, bearing on the classification of the older rocks of Devon and Cornwall, we might add some remarks on the mineral structure of the two counties—on the existence of red conglomerates among the beds of the Cornish *killas*—and on the large tracts, both of North and South Devon, filled with rocks identical in structure with the most ordinary forms of old red sandstone. But we forbear to dwell on such facts as these, wishing to build our present conclusions chiefly on zoological evidence.

Guided then by the evidence already stated, and the conclusions to which it seemed to point, we have re-examined the fossils obtained, either by our own labours or by the assistance of our friends, from the two counties; and the conclusion arrived at by Mr. Lonsdale respecting the age of the South Devon limestone, we now apply without reserve both to the five groups of our North Devon section, and to the fossiliferous slates of Cornwall.

This is undoubtedly the greatest change which has ever been attempted at one time, in the classification of British rocks. But all the facts brought to light by those, who have laboured in the same field with ourselves, were gradually leading towards the same point; and the establishment of the Silurian organic types must before long have made the change inevitable*.

So far from thinking ourselves rash and hasty in drawing the preceding

* The reasons for the new classification of those stratified rocks of Devon and Cornwall which are below the culm-measures, were briefly stated by the authors in a paper published in the Philosophical Magazine for April 1839.

conclusion, we think we may rather be accused of being over-cautious and tardy in accepting evidence, however opposed to commonly received opinions. But, on this score, we may state in our justification, that a considerable part of our fossil evidence has been but recently brought to light. Several of the organic remains, from the neighbourhood of New Quay, on the north coast of Cornwall, which we owe to the kindness of Mr. Carlyon, and many other good specimens given to us by our friend Mr. Pattison of Launceston, have been but very recently submitted to a careful examination; and the beautiful collection of Plymouth fossils committed to our care by Mr. Hennah, was only unpacked, in consequence of unavoidable delays, during the present spring. An examination of this collection by one of the authors, assisted by Mr. Lonsdale, Professor Phillips, and Mr. James Sowerby, confirmed the previous conclusions of Mr. Lonsdale, which were chiefly founded on Mr. Austen's collection; and, as before stated, led the way to our proposed classification of the Cornish and Devonian formations*.

At first, we did not intend to give any map among the illustrations of this paper; as it was thought that any of the published geological maps of England would enable the reader to follow our details. But it has now been thought better to give a reduced map of the country we describe, chiefly taken from the corrected Index geological map attached to Mr. De la Beche's Report on the Geology of Cornwall and Devon; in order that we may convey, at a single glance, the connexion between the structure of Devonshire and Cornwall, and the directions in which our several sections are drawn†. All details of structure are, however, intentionally avoided, and the stratified groups are all represented by two colours. In this way we mean to convey our belief, that the inferior groups all belong to one system, viz. that of the old red sandstone. There may, indeed, among the lowest rocks of the two counties, be some which belong to a still lower system. But if such there be, we are unable to point them out; and we think it best and safest, as far as regards their classification, to merge them all at present in one common colour.

Neither did we at first intend to publish any figures of the fossils derived from the several groups above described. But it was urged, that a paper proposing such great changes in the classification of our older rocks would not be well received, or even understood, without more graphic proofs than mere

* Since this paper was read, Mr. Williams has permitted us to examine his excellent collection of fossils from Cornwall and North Devon. We may allude to them generally as confirming our views; but none of them will appear among the illustrations of this paper, as their specific descriptions are, we trust, hereafter to be given by Professor Phillips.

† See Plate L.

verbal descriptions. In the subjoined plates (Pl. LII. to LVIII.) we have therefore figured some of our best fossils. The figures and determination of the fossil shells are all by Mr. James Sowerby: any notice we may take of the corals will be given on the authority of Mr. Lonsdale.

We might perhaps now content ourselves by simply giving a list of the fossils derived from the respective deposits, and then leave the reader to draw the proper conclusion from the facts before him; but we think it advisable, in the first place, to put our evidence in a more general and popular form. In our previous paper, the successive groups are described in the ascending order in which we first observed them, during our traverse from the north to the south coast of Devon. But in noticing the fossils, it is almost necessary (as our sections have no well-defined base) to take a reversed order, and commence with the upper division of the culm-measures.

1. *Culm Measures.*—In the first place, then, we have nothing to add to the evidence given by the vegetable fossils of this upper division of the culm-measures, or to the conclusions we drew from it. On this point, therefore, we merely refer to our former communication (*suprà*, p. 669, *et seq.*). The black limestone of the lower division contains many shells of the genus *Posidonia*, three or four species of *Goniatites*, and two or three other genera not yet well ascertained. Now the genus *Posidonia* is found abundantly both in the upper and lower limestone shales, of the true carboniferous series of England and Ireland: for example, in the *calp* of Ireland, which is in the place of the lower shales, and in the upper limestone shales of Northumberland, not far below the millstone grit. There is a species in Northumberland, which makes a very near approach to a species very abundant in the black culm limestone. Again, of the *Goniatites* of the culm limestone, there are three species very closely related to those of the mountain limestone*. Among them is one which Professor Phillips is unable to separate from the *G. Henslowi*, found in the great scar limestone of the Isle of Man; and it deserves remark that this species occurs also in the Petherwin group, below the culm-measures,—a fact which tends to prove the reality of a passage from the base of culm-measures into the next inferior group.

Where then shall we place the culm limestone, and carbonaceous shales that form a part of it? If we arrange them with the upper shales of the mountain limestone, then nearly the whole culm-trough of Cornwall and Devon will be the equivalent of the middle and upper divisions of our true carboniferous series. This view was adopted by Prof. Phillips when he published his index map of the British Isles. But if we identify the black, calcareous, culm shales

* Report on the Geology of Cornwall, &c. p. 117.

with the *calp* of Ireland, or the lower limestone shales of England, the culm series of Devon will, as a whole, be very nearly the equivalent of our entire carboniferous series. Considering, however, the enormous thickness of the whole culm-measures and the paucity of fossils in all the inferior beds of its lower division, we continue to place its base in a doubtful position. This is a measure of necessary caution, especially when we bear in mind the extreme difficulty, in the northern parts of our island, of drawing any precise line of demarcation between the base of the coal-measures and the old red sandstone*.

Before the sections of North Devon had been made out, the culm-measures were naturally included in the vast deposit of graywacké, of which we knew neither the beginning nor the end. But to merge them in that series now, is to reject all the direct evidence we possess, and all the analogies supplied by the corresponding parts of our island. Lastly, there seems now to be no difference of opinion as to the superficial distribution of the culm-measures; for the boundary line indicated roughly by us in 1836, and more in detail in our previous paper, agrees, as far as it goes, with that lately published by Mr. De la Beche.

2. *Fossils of Petherwin and Barnstaple.*—The fossiliferous slates in the neighbourhood of these two places rise immediately from beneath the base of the culm-measures. Their position is therefore symmetrical, and, as before stated, they appear on the whole to form a mineral passage into the overlying system. In this way, we establish a mineralogical connexion between the North Devon and Cornish sections. But the connexion is made incomparably more secure by help of the fossils. Those we have obtained from Barnstaple, Croyde Bay, Marwood, &c. (all of them places in the highest division, No. 5, of our North Devon section,) certainly agree as a group with those of Petherwin, and have many species in common, as will appear by our lists. It is enough for our present purpose to quote the following; *Spirifer attenuatus, S. bisulcatus, Orthis interlineata, Atrypa concen-*

* The difficulty we have pointed out does not arise from any doubt respecting a great principle of classification, but merely involves the adjustment of a boundary line. One of the best illustrations of this difficulty is seen on the east coast of Scotland, north of St. Abb's Head. The old red sandstone first appears as a conglomerate, resting transversely on the edges of the graywacké; and then passes so insensibly into the *red carboniferous rocks*, that, through a considerable extent of coast, it is hardly possible to draw any well-defined line between the two formations. We may, however, observe by the way, that there are several pretty extensive tracts coloured as old red sandstone in Macculloch's Geological Map of Scotland, which we believe every geologist who was guided by the English types would class with the lower division of the mountain limestone; and there are one or two places in Dumfries-shire, where we think he has confounded the new with the old red sandstone.

trica, A. decussata, A. striatula; also a smooth and a plaited species; *Leptæna caperata, L. scabricula*? *Pecten s. n. Pallastra s.n.** All these shells are found both among the calcareous slates of Petherwin and in the calcareous slates near Barnstaple; and several of the species common to both localities are extremely abundant. That there are several species among the Petherwin fossils which have not been yet found among those of Barnstaple, takes not at all from the force of our direct evidence. It deserves remark, that there are several species in these upper groups which do not appear in the lower; and among those we may notice the Goniatites and the Endosiphonites†, (Clymenia of Munster,) as they seem to point towards the types of the carboniferous period.

In the lower division of the Barnstaple calcareous slates occur the Marwood fossils, given in our lists, among which are several species of *Cucullæa*. These shells are associated with the genus *Bellerophon*, one of which, as before stated, cannot be distinguished from the *Bellerophon globatus* of the old red sandstone. Very nearly on the strike of the Marwood beds occur the fossil plants of the Sloly quarries. According to Professor Lindley, (*antè*, p. 683.) one of the species belongs either to a *Stigmaria* or a *Lepidodendron*; while others are new or incapable of determination. Professor Henslow, who has recently examined a good series of fossil plants from the same locality, informs us, that he is able out of them to distinguish three or four species, not one of which he believes to have been described in the published works of Sternberg, Brogniart, or Lindley. Either of these results would fall in with our present views. We undoubtedly consider the Sloly beds as out of the limits of the carboniferous series, and therefore we should expect that its fossils would conform to an older type. On the other hand, the appearance of a few species of the true carboniferous fossils in the upper division of the old red sandstone would be in perfect harmony with what we know of the geological distribution of organic forms. But the assumption that the ordinary species of coal-measure plants may exist in the *old graywacké* rocks of an entirely distinct period, takes for granted conditions which are not supported by the evidence of the Devonian sections, as we now interpret them.

We are unwilling to push our present remarks any further; but we can

* Some of the fossils quoted are of doubtful species; but the doubt does not apply to the identification of the individual specimens from the opposite sides of the culm-trough.

† The appropriate name of *Endosiphonite* had been given to the genus by Mr. Ansted before he was acquainted with the previous discovery of Count Munster. The name *Clymenia* is by no means so good; but having the priority, ought to be retained. We cannot but regret that the original name (*Planulites*) was rejected by Count Munster, as it harmonizes with the general nomenclature of fossil *Cephalopodes*, better than his present name *Clymenia*.

hardly avoid surmising that the peculiar plants of the "*terrain d'anthracite inférieur*" of Professor Voltz, and those of a supposed similar age in Brittany and other parts of France, may eventually be found to be on the same parallel with this portion of our North Devon series.

3. *Inferior Groups of the North Devon Section.*—The number of fossils hitherto collected is far too small to justify us in affirming to what extent the fossils of the Ilfracombe calcareous slates (North Devon Section, No. 3.) differ from those of Barnstaple. A few species are certainly common to both, among which we may quote two species of *Leptæna* and a *Pecten* (see the list). Corals abound in the Ilfracombe slates, though the species are not numerous. The *Favosites polymorpha* (never yet discovered in the mountain limestone, or below the upper Silurian groups,) is the most abundant. With it is another entirely new species, which also abounds in the Cornish fossiliferous strata beneath the culm-measures. On the whole we may state, on the authority of Mr. Lonsdale (from whom alone we have derived any accurate information on this head), that the Devonian corals are all either of species peculiar to these groups or such as occur only in the higher part of the Silurian system.

Immediately below the Ilfracombe calcareous slates, are some hard strong beds, with numerous impressions of a large cordiform bivalve, unlike anything we remarked in the overlying beds. From the lowest group of all (North Devon Section, No. 1.) we have very few well-preserved fossils: among them are many beautiful casts of a *Fenestella*, and among the bivalves is an Orthis of a new species, and a Spirifer identical with one found near Barnstaple (*Spirifer attenuatus* ?).

Such is the summary of the evidence given by the fossils of the North Devon section; and imperfect as we acknowledge it to be, we think it sufficient to bear out our proposed classification; especially as we know of no conflicting fossil evidence that is in any way opposed to it.

3. *South Devon and Cornwall.*—In the comparison of the mineralogical groups of North and South Devon, we can add nothing to what has been stated in a former paper. We could not bring the great upper South Devon limestone into direct comparison with the calcareous zone of Barnstaple; because, in that case, the great slate formation, which overlies the Plymouth limestone, would have no representative in North Devon. We therefore provisionally placed the great calcareous group of South Devon on a parallel with the lower fossiliferous groups toward the northern extremity of our section. The fossils appear on the whole to bear out this classification.

First, then, as to the South Devon corals.—None of them have been found in the mountain limestone, several are new or not known to occur in the Si-

lurian system, and some agree specifically with corals of the highest Silurian groups. On this point we rely on Mr. Lonsdale's determination; and we give it in his own words:

Favosites polymorpha, (Goldfuss, Pl. XXVII. f. 4. Silur. Syst., Pl. XV. f. 2.). Common in the Plymouth* and Ogwell* limestones, and it occurs also at Barton and Torquay, and in slate at New Quay, Cornwall.

——— *spongites* (Goldf., Pl. XXVIII. f. 1. Silur. Syst., Pl. XV. f. 8, 9.). Plymouth and Ogwell limestones.

——— ? *ramosa*, (Brassart). The Rev. D. Williams's cabinet. Near Chudleigh.

——— *Gothlandica*, (Goldf., Pl. XXVI. f. 3. Silur. Syst., Pl. XV. *bis*, f. 3, 4.). Plymouth limestone; apparently scarce.

——— *fibrosa*, (Goldf., Silur. Syst., Pl. XV. *bis*, f. 7.). A single imperfect specimen of this species is in Professor Sedgwick's collection from Fowey; it occurs also at Barton, near Mary Church.

Porites pyriformis†, (Ehrenberg, Goldf., Pl. XXI. f. 7. Silur. Syst., Pl. XVI. f. 2.). Common in the Ogwell limestone; it occurs also near Plymouth, and Mary Church. Pl. LVIII. fig. 4.

Cyathophyllum turbinatum, (Goldf., Pl. XVI. f. 8. Silur. Syst., Pl. XVI. f. 11.). A fragment in the Rev. R. Hennah's collection.

——— *cæspitosum*†, (Goldf., Pl. XIX. f. 2.). Very common near Plymouth and Ogwell; it occurs also near Torquay. Pl. LVIII. f. 8 to 8 d.

Astrea (*Favastrea*) *helianthoides*, (De Blainville, *Cyathophyl. helianthoides*, Goldf., Pl. XX. f. 2.). Two specimens in calcareous slate from near Plymouth in the Rev. R. Hennah's collection, and one in limestone in the Museum of the Geol. Soc.; presented by the late Mr. Harvey.

—— (———) *pentagona*†, (De Blainville, *Cyathophyl. pentagonum*, Goldf., Pl. XIX. f. 3.). Plymouth, Ogwell, and Torquay limestones; not very abundant. Pl. LVIII. f. 1, 1 a.

—— (*Siderastrea*, De Blainville,) *Hennahii*†, (sp. n.). Plymouth limestone and Barton Quarry near Mary Church. Pl. LVIII. f. 3 to 3 b.

Strombodes vermicularis, (*Cyathophyl. vermiculare*, Goldf., Pl. XVII. f. 4.). Common in the Plymouth and Ogwell limestones. Pl. LVIII. f. 7, 7 a.

Stromatopora polymorpha†, (Goldf., Pl. LXIV. f. 8.). Two specimens from Appleway and near Teignmouth, in the collection of Mr. D. Sharpe. Pl. LVIII. f. 2.

Coscinopora placenta?†, (Goldf., Pl. IX. f. 18.). Common in the Ogwell and Plymouth limestones; it occurs also at Torquay, Whatcomb, Appleway, and Newton Bushel. Pl. LVIII. f. 5 to 5 d.

Turbinolia? *celtica*†, (Lamouroux, Pl. LXXVIII. f. 7, 8.). Dinas Cove, Padstow, Berry Pomeroy, and Fowey. Pl. LVIII. f. 6.

Fenestella antiqua†, (*Gorgonia antiqua*, Goldf., Pl. XXXVI. f. 19. Silur. Syst., Pl. XV. f. 15–18.). Common at Fowey, Petherwin; in yellow rotten slate in the neighbourhood of Plymouth; in North Devon the fossil occurs at Saunton, Linton, ? and north of Barnstaple. Pl. LVIII. f. 10 to 10 b.

Cystiphyllum Damnoniense†, (sp. n.). Very abundant near Ogwell; it occurs also near Plymouth, but sparingly. Pl. LVIII. f. 11 to 11 b.

Scyphia turbinata†, (Goldf., Pl. II. f. 13.) Slate near Plymouth. Pl. LVIII. f. 9.

The most abundant of the above species in the limestones of South Devon are *Favosites polymorpha*, *Porites pyriformis*, *Cyathophyllum cæspitosum*, *Strombodes vermicularis*, *Coscinopora placenta*, and *Cystiphyllum Damnoniense*, only the three first of which have been noticed in the Silurian System of England. The limestones are further characterized by the total absence of *Catenipora escharoides*, and by the absence or extreme scarceness of many of the corals most abundant in the Wenlock and lower Silurian formations.

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* The specimens from the Plymouth limestone, are principally in the cabinet of the Rev. R. Hennah; those from the Ogwell limestone in that of Mr. R. A. C. Austen; and those from Barton, near Mary Church, and Teignmouth, in the collection of Mr. Daniel Sharpe.

† The species thus distinguished are figured in Pl. LVIII., either on account of their being new, or characteristic of the Devonshire limestones.

Coupling this account with the near resemblance of some of the South Devon shells to known fossils of the mountain limestone, we at once establish our main position, that the South Devon fossils are of an intermediate type between those of the Silurian and carboniferous systems. It also follows from the same evidence, that the North and South Devon corals belong to rocks which are very nearly on the same parallel, as the most abundant corals of the lower North Devon groups agree specifically with the most abundant corals of the Plymouth and Tor Bay limestones.

As far as regards the fossil shells, we must refer to the accompanying lists. We may however remark, in our present summary, that we have shells in the Plymouth limestone which make a near approach to *Terebratula Wilsoni*, *Atrypa orbicularis*, *Orthis depressa*, *Pileopsis vetustatis*, *Nerita Haliotis*, and *Orthoceratites circularis*, of the upper Silurian rocks. Most of them, however, when closely examined, present some points, we think, of specific difference. On the other hand, this limestone contains some genera and species very nearly resembling certain fossils (such as *Pecten dissimilis* (Phillips), *P. plicatus* (Sowerby), *P. arenosus* (Phillips), *Terebratula acuminata* (Sowerby), *Producta analoga* (Phillips), &c. &c.) of the carboniferous limestone. Lastly, we may remark, that many species in the Plymouth limestone (and those, we believe, the most abundant) are quite distinct from the fossils both of the carboniferous and Silurian systems; among which we may point out a very large *Atrypa*, *Buccinum spinosum*, a large *Natica*, and several small univalves. (See the Lists.)

We have many fossils from the neighbourhood of Newton Bushel, chiefly, however, in the form of siliceous casts: we forbear, however, to dwell on them, as Professor Phillips and Mr. Austen are, we believe, both engaged in their description. Some of them agree specifically with shells of the Plymouth limestone; others are new; several of them nearly approach the forms of the mountain limestone (as we learn from the description of Mr. Austen, and the recently published "*Report*" of Mr. De la Beche); and the corals, at least the most abundant species, agree with corals of the Plymouth and Ilfracombe limestones.

Such is a brief summary of the results arising out of an examination of the South Devon fossils; and the conclusion to which they point appears to us absolutely inevitable, viz. that the South Devon series is intermediate between the carboniferous and Silurian systems, and consequently on the parallel of the old red sandstone.

After the details of our previous communication, it is evident that all the calcareous slates on the south-eastern side of Cornwall are of the age of the owest group of the South Devon section, and therefore probably in the lower

portion of the old red sandstone. On the north-western coast of the county, we were preceded by Mr. De la Beche, and we must refer our readers to the many excellent details of his "Report." A few of our fossils from both coasts will appear in the appended lists; and, imperfect as they are, they appear to sanction our general views. The Petherwin, and we think also the highly crystalline Tintagel slates, appear to be of the age of the Barnstaple slates, and are therefore in the upper part of the old red sandstone. Such is a general summary of the evidence on which our proposed classification is founded; and the result is given in our accompanying map. (Pl. L.)

Concluding Remarks, &c.

Having stated the grounds on which we have endeavoured to establish the classification of the stratified rocks of Devonshire and Cornwall, it may be well, before we quit the subject, to notice certain objections that have been urged against our views.

1. In the first place, our evidence may be considered defective, from the absence of the carboniferous limestone, which in many parts of the British Isles has so striking a position between the coal measures and the old red sandstone. To this we might reply, by pointing out several instances in the central counties of England, where the carboniferous system rests on the lower formations, without the intervention of any bands of limestone. We would, however, rather appeal to a more general fact—that the mountain limestone, after forming in the north of England a great succession of beds, and rising into mountains of considerable elevation, gradually thins out in its prolongation towards the south; so that in South Wales it occupies but one well-defined band, and at length so entirely dies away in the western extremity of Pembrokeshire, that the overlying culm measures and hard grits rest, in one district, immediately on older rocks, without the intervention of any calcareous matter whatsoever. With such a fact before us, we have no reason to be surprised at the absence of the mountain limestone, where the culm measures reappear in Devonshire and Cornwall.

Considering the enormous thickness of the culm measures of these counties, it is by no means improbable that the mountain limestone is there represented by contemporaneous deposits of a different mineral type. For surely it is now needless for us to prove that rocks, identical in geological position, may entirely change their lithological structure, as they pass from one county to another. A change of structure, however, implies a change of conditions during the time of the deposit; and such a change might greatly modify the forms of animal life. In this way we might, perhaps, explain the absence of

many of the best-known mountain-limestone fossils from the carbonaceous shales and sandstones of the lower culm measures of Devonshire.

2. Again, it has been objected, that the fossils of the Devonian groups, now classed with the old red sandstone, are not the same with the known fossils of that formation.

We allow that the fossil fish of the old red sandstone have not yet been discovered among the Devonian rocks. But how can we build any conclusion on such a mere negative fact? The same genera and species are not distributed through the whole extent of every formation. Moreover, who can tell that fossil fish will not hereafter be discovered among the calcareous slates of Devonshire? But there is a more positive objection to be noticed, viz. that the known fossil shells of the old red sandstone differ greatly from those we have obtained from the Devonian groups. To this we may reply, that the shells hitherto described from the old red sandstone are derived exclusively from its very lowest beds, which probably do not appear on any of our previous sections. These objections are, however, of little weight against the broad fact (which, in truth, forms the sum and substance of our evidence), that the fossils described in this paper are of a type intermediate between the types of the carboniferous and Silurian systems*.

3. The extreme change, among the formations we have described, of the ordinary mineral type, is another objection to our views. It has been noticed in various parts of our two memoirs, and considered at some length in our paper, of April last, in the Philosophical Magazine; we need not, therefore, dwell upon it now. But we may briefly state, that as the old red sandstone exhibits so many changes of structure, in its range from the Orkneys to the north side of the Bristol Channel, we have no difficulty in admitting still fur-

* Were it true, that species abounding in the mountain limestone, and disappearing in the descending sections, appeared again in still lower parts of the gray-wacké series; there would then be comparatively little weight in our evidence, or certainty in our conclusions. But we have no such antagonist fact now to contend with. In a paper, published (April 1839) in the Philosophical Magazine, we expressed our hopes that the views of classification we then threw out might cast some light on the structure of the south of Ireland; and before our paper was struck off, we became acquainted with the contents of a memoir by Mr. C. W. Hamilton, to which we alluded in a postscript. At the very meeting which followed that on which our present paper was read before the Geological Society, Mr. Griffith exhibited a copy of his Geological Map of Ireland, and read a memoir, illustrated by sections, and accompanied by fossils; by help of which he showed, we think, to demonstration, that there is no anomalous recurrence of the carboniferous fossils among the true gray-wacké rocks of the south of Ireland. His sections of the rocks immediately below the mountain limestone exhibited a broken, imperfect series; most instructive, however, in one respect, as showing an undoubted ascending passage into the limestone.

ther changes, if supported by the evidence of fact or rational analogy. What difficulty is there in believing that a marine formation should, in one part of the world, have gone forward so tranquilly as to allow all the ordinary operations of animal life; while, in another part, the deposits of the ocean were interrupted or modified by rude mechanical movements, incompatible with the existence of organized beings? We see no difficulty whatsoever in the mineral structure of what we now regard as the old red sandstone of Devonshire and Cornwall. The classification we adopt is derived from its own appropriate evidence; and it at the same time removes the greatest difficulties presented by the unexplained phenomena of our older formations; gives a natural sequence and meaning to their history; and, we may add, gives a symmetry to the disposition of the colours on our geological maps, which they never had before.

The strongest proofs are given in this and our previous paper, of the insufficiency of mineral character, taken alone, to determine the epoch of any doubtful formation: and as the term *gray-wacké* has done much disservice to geology, by inducing observers to merge, under one unmeaning name, deposits belonging to distinct periods in the history of the earth, we venture to hope that the word may henceforth be discarded as a term of classification. Used for the mere purpose of mineral description, we can of course make no similar objections to it.

4. Lastly, we may remark, that in all the descriptions, both of this and our previous paper, we have, for obvious reasons, drawn our analogies from the nearest formations of our own island. But we cannot forbear expressing our belief, that the series of rocks of Devonshire and Cornwall, above described, may serve to clear up some of the difficulties in the classification of the older formations of the continent of Europe, where the old red sandstone has seldom been found, at least in what has been hitherto regarded as the ordinary British type. But now that the old red sandstone has been exhibited in such a different form, on such a vast scale, and with its own series of organic remains, we have little doubt that its true equivalents will be found distributed through various parts of Europe. To obtain, as far as possible, satisfaction on some of these points, is the first task we propose to ourselves during the investigations of the approaching summer.

Though the term old red sandstone, when designating great groups of rocks like the Cornish *killas* and Devonian slates, should involve no error of classification, still it would, mineralogically, be most inappropriate. We purpose therefore, for the future, to designate these groups collectively by the name *Devonian system*, as involving no hypothesis, and being agreeable to

analogy. Thus the terms Carboniferous system, Devonian system, Silurian system, and Cambrian system, will represent a vast and apparently uninterrupted sequence of deposits; each having, as a whole, zoological and (often also) mineralogical characters of its own, yet each passing into the system next in order by almost imperceptible shades of difference. The old *palæozoïc* rocks appear, therefore, notwithstanding their enormous scale, and the wide diffusion of the same organic types, to have been formed in subordination to the same laws which, in after periods, produced the more clear succession of our secondary formations.

Section from the Foreland on the Bristol Channel to the English Channel. For the details of the portion between the Foreland and Dartmoor, see Plate LI. fig. 1.

LIST OF ORGANIC REMAINS principally contained in the Cabinet of the Rev. R. Hennah, F.G.S., or collected by the Authors. The Corals have been determined chiefly from Specimens in the possession of Mr. Austen and Mr. Daniel Sharpe. A MS. Catalogue of Devonshire Fossils by Mr. Austen has also been used in preparing the Table.—May 30, 1840.

Genera and Species.	Authors and References. The numerals refer to the plates which illustrate the memoir.	Groups and Localities.			
		Culm Measures, p. 693.	Barnstaple and Petherwin Group, p. 694.	Lower Groups N. Devon, p. 696.	Lower Groups, South Devon, p. 696.
Plants, p. 681.					
Pecopteris lonchitica	P. blechnoides & P. lonch. A. Brongn. 84. f. 1-7. Filic. lonchiticus, Schloth. Flor. d. Vorw. 11. f. 32. Alethopteris lonchitid. & A. vulgat. Sternb. Flor. d. Vorw. 55.	Bideford.			
——— muricata	A. Brongn. 95, f. 3, 4, 97.	Ibid.			
——— Serlii	A. Brongn. 85. Foss. Fl. 202. De la Beche, Rep. p. 126.	Ibid.			
Neuropteris gigantea	Sternb. Tent. Fl. Primord. 22. A. Brongn. 69. Foss. Fl. 52.	Ibid.			
——— cordata	A. Brongn. 64, f. 5. Foss. Fl. 41.	Ibid.			
——— Loshii	A. Brongn. 72, f. 1, 73. Foss. Fl. 4, 9, De la Beche, Rep. 126.	Ibid.			
——— heterophylla	A. Brongn. 71, 72, f. 2. Foss. Fl. 183, 197, 200. De la Beche, Rep. p. 126.	Ibid.			
Sphenopteris latifolia	A. Brongn. 57, f. 1-4. Foss. Fl. 156, 178.	Ibid.			
——— acuta	A. Brongn. 57, f. 5. De la Beche, Rep. p. 126.	Ibid.			
Calamites undulatus	A. Brongn. 17, f. 1, 4.	Ibid.			
——— arenaceus?	A. Brongn. 25, f. 1. 26, f. 3-5.	Ibid.			
Poacites cocoina	Foss. Flora, 142 B.	Ibid.			
Asterophyllites foliosa	Foss. Flora, 25.	Ibid.			
Cyperites bicarinata	Foss. Flora, 43, f. 1-2.	Ibid.			
For observations on the Sloly Vegetable Remains, see pp. 683, 695.					
Corals, p. 697.					
Scyphia turbinata	Goldf. 2, f. 13. LVIII. 9.				Plymouth. [way, Torquay.
Coscinopora placenta?	Goldf. 9, f. 18. LVIII. 5-d.				Ibid. Ogwell, Newton, Apple-
Petraia (Munster) celtica	Turbinolia Lamx. Exp. M. 78, f. 7, 8. LVIII. 6.				Dinas Cove Padstow, Berry Pomeroy, Crownall Bay.
Strombodes vermicularis	Cyathophyl. Goldf. 17, f. 4. LVIII. 7-a.				Plymouth, Ogwell.
Cystiphyllum Damnoniense	LVIII. 11-b.				Ibid. Ibid. Newton.
Cyathophyllum turbinatum	Goldf. 16, f. 8. Silur. Syst. 10, f. 11-a.				Ibid.
——— cæspitosum	Goldf. 19, f. 2. Silur. Syst. 16, f. 10. LVIII. 8-d.			Ilfracombe.	Ibid. Ibid. Torquay.
——— quadrigeminum?	Goldf. 18, f. 6.			Ibid.	
Astrea pentagona	De Bl. Man. d'Actin. 375. Cyathophyl. Goldf. 19, f. 3. LVIII. 1-a.				Ibid. Newton.
—— helianthoides	De Bl. Man. d'Actin. 375. Cyathophyl. Goldf. 20, f. 2.			Ibid.	Ibid.
—— Hennahii	LVIII. 3-b.			Ibid.	Ibid. Barton. Marychurch.
Porites pyriformis	Ehrenb. Silur. Syst. 16, f. 2 e. LVIII. 4-f.			Ibid.	Ibid.
Favosites polymorpha	Goldf. 27, f. 4. Silur. Syst. 15, f. 2.			Ilfracombe.	Ibid. Newton, Barton, Torquay,
——— spongites	Goldf. 28, 1 f. Silur. Syst. 15 bis. f. 8-a.				Ibid. Ibid. [New Quay.
——— Gothlandica	Goldf. 26, f. 3. Silur. Syst. 15 bis. f. 3-4.				Ibid. Ibid.
——— fibrosa	Goldf. Silur. Syst. 15 bis. f. 6.			Linton.	Fowey, Barton.
———? ramosa	Brassart Mus. Geol. Soc. London.			Ilfracombe.	near Chudleigh.
Stromatopora polymorpha	Goldf. 64, f. 8. LVIII. 2.		Saunton.		Appleway.
Fenestella antiqua	Gorgonia, Goldf. 36, f. 3. Silur. Syst. 15, f. 6. LVIII. 10-b.		Croyde Bay, Petherwin.	Linton.	Plymouth, Fowey.
Pleurodictyum problematicum	Goldf. 38, f. 18.				West Ogwell.
Cupressocrinites	Goldf.				Plymouth, Cullompton.
Crinoidal remains, too imperfect to be determined, occur at Barnstaple, &c., see Description of the Plates.					
Shells, (See Description of Plates.)					
Terebratula prisca	Schloth. 17, f. 2.				Plymouth, Newton.
——— ferita	Von Buch. Terebrat. p. 76, 2 f. 37.				Ibid.

Genera and Species.	Authors and References. The numerals refer to the plates which illustrate the memoir.	Groups and Localities.			
		Culm Measures, p. 693.	Barnstaple and Petherwin Group, p. 694.	Lower Groups, N. Devon, p. 696.	Lower Groups, South Devon, p. 696.
Terebratula acuminata	Sow. M. C. 324, f. 13. 495, 1-3. Geol. Yorks. 12, f. 4-9.		Barnstaple.		Plymouth, Newton.
——— concentrica	Von Buch. Terebrat. p. 103.				Newton Bushel.
Orthis plicata	LIII. 10.		Ib. n^r Pether.		
—— interlineata	LIII. 11, LIV. 14.		Landlake, Lear y, &c.		
—— tenuistriata	LVII. 12.		Morebath.		
Spirifera calcarata	LIII. 7. (S. attenuata, p. 694.)		Barnstaple.		
—— disjuncta	LIII. 8. LIV. 12, 13. (S. bisulcata, p. 694.)		Ib. Petherw.		
—— inornata	LIII. 9.			Ilfracombe.	
—— extensa	LIV. 11. (S. attenuata, p. 694.)		Ib. Ib. Saunton.		
—— gigantea	LV. 1-4.				Tintagel.
—— costata	LV. 5-7.				Ibid. Fowey.
—— ? crenistria	LVII. 7. Phillips 9, f. 6.				Plymouth.
—— nuda	LVII. 8.				Ibid.
—— pulchella	LVII. 9.				Ibid.
—— subconica, var.	LVII. 10. Martin Pet. Derb. 47, f. 6-8.				Ibid.
—— affinis	LVII. 11.				Ibid.
—— aperturata	Schloth. 17, f. 1. Trigonot. Bronn. Leth. Geog. 2, f. 13.				Newton Bushel.
—— trapezoidalis	Dalman. Silur. Syst. 5, f. 14.				Ibid.
—— speciosa	Schloth. 16, f. 1. Trigonot. Bronn. Leth. Geog. 2, f. 15.				Ibid.
—— ostiolata	Schloth. 17, f. 3. Trigonot. Bronn. Leth. Geog. 2, f. 14.				Ibid.
—— cassidea	Trigonotreta, Bronn. Lethæa Geognos. 2, f. 9.				Ibid.
—— oblata	Sow. M. C. 80. Trigonot. Bronn. Leth. Geog. 2, f. 16.				Ibid.
Strygocephalus Burtini	Terebrat. porrecta M. C. 576, f. 1.				Newton, Bradley.
——— giganteus	LVI. 10, 11.				Ibid. Plymouth.
Atrypa oblonga	LIII. 6.		Barnstaple.		
—— hispida	LIV. 4.		Petherwin.		
—— decussata	LIV. 5.		Ibid.		
—— indentata	LIV. 6. (A. concentrica, p. 694.)		Ib. Barnst.		
—— subdentata	LIV. 7.		Ibid.		
—— unguiculus	LIV. 8.		Ibid. Ibid.		
—— triangularis	LIV. 9.		Ibid.		
—— striatula	LIV. 10.		Ibid. Ibid.		Fowey ?
—— juvenis	LVI. 8.				Plymouth.
—— Lachryma	LVI. 9.				Ibid.
—— plebeia	LVI. 12, 13.				Ibid.
—— triloba	LVI. 14.				Ibid. Newton Bushel.
—— pugnus	LVI. 15, 18. Terebratula pugnus, M.C. 497.				Ibid.
—— protracta	LVI. 16.				Ibid.
—— crenulata	LVI. 17.				Ibid.
—— desquamata	LVI. 19–22.				Ibid.
—— aspera ? var.	LVI. 23. (A. orbicularis, p. 698.)				Ibid.
—— cuboides	LVI. 24.				Ibid.
—— latissima	LVI. 25.				Ibid.
—— squamosa	LVII. 1.				Ibid.
—— fallax	LIV. 15. (Ter. pleurodon. Phill. XII. 25,26.)		Ibid. Ibid.		
—— impleta	LVII. 2.				Ibid.
—— sphærica	LVII. 3.				Ibid.
—— implexa	LVII. 4. (Terebrat. Wilsoni, p. 698.)				Ibid.
—— primipilaris	LVII. 5, 6.				Ibid.
Leptæna caperata	LIII. 4. (L. scabricula, p. 694.)		Barns Pethr.		
—— sordida	LIII. 5.		Petherwin.	Linton.	
—— prælonga	LIII. 29.		Croyde Bay.		
—— Fragaria	LIV. 3. LVI. 5, 6.		Petherwin ?		Plymouth.
—— analoga	LVI. 3. (Prod. analoga, p. 698.)		Barnstaple.		Plymouth.
—— rugosa?	LVI. 4.				Ibid.
—— interrupta	LVI. 7.				Ibid.
—— reticulata	LVII. 7.				[ton.
Calceola sandalina	Lamark. Anim. sans Verteb. 2nd Edit. T. p.				Chircombe Bridge, near New-

Genera and Species.	Authors and References. The numerals refer to the plates which illustrate the memoir.	Groups and Localities.			
		Culm Measures, p. 693.	Barnstaple and Petherwin Group, p. 694.	Lower Groups, N. Devon, p. 696.	Lower Groups, South Devon, p. 696.
Corbula Hennahii	LVI. 1.				Plymouth.
Pullastra? antiqua	LIII. 28.		Marwood.		
Cardium aliforme	LVI. 2. (Pleurorhyn. minax Phill. 5, f. 27.)				Plymouth.
Megalodon cucullatus	Sow. M. C. 568.				Bradley.
Cucullæa unilateralis	LIII. 23.		Marwood.		
——— Trapezium	LIII. 24.		Ibid.		
——— angusta	LIII. 25.		Ibid.		
——— Hardingii	LIII. 26, 27.		Ibid.		
Avicula Damnoniensis	LIII. 22.		Ibid.		
——— subradiata	LIV. 1.		Petherwin.		
——— pectinoides	LIV. 2.		Ib. Barnst.		
Posidonia lateralis	LII. 1.	nr Barnst.			
——— Becheri	LII. 2, 3, var. 4.	Ibid.			
——— tuberculata	LII. 5.	Budle nr Bambro'.			
Pecten nexilis	LIII. 1, 2.		Barnstaple.		
——— transversus	LIII. 3.		Ibid.		
——— plicatus	Sow. M. C. 83, f. 3.				Plymouth.
——— arenosus	Phill. Geol. Yorks.				Ibid.
Pileopsis vetusta	LVII. 13. (P. vetustalis & Nerita haliotis, p. 698.				Ibid.
Nerita? deformis	LVII. 14.				Ibid.
——? speciosa	LVII. 15.				Ibid.
Euomphalus radiatus	Goldf. M. S.				Newton Bushel.
Trochus Boueii	Steininger, Mem. Geol. Soc. France, t. i. 23, f. 4.				near Newton Bushel.
Turbo subangulatus	LVII. 18.				Plymouth.
——- cirriformis	LVII. 19, 20.				Ibid.
Turritella abbreviata	Sow. M. C. 565. f. 2.				Ibid. Bradley.
Pleurotomaria aspera	LIV. 16.		Peth.,Landlake.		
——— impendens	LVII. 16.				Plymouth.
——— cirriformis?	LVII. 17.				Ibid.
Murex Harpula	LVII. 21, Sow. M. C. 88, f. 5.				Ibid. Bradley.
Buccinum acutum	LVII. 23. Sow. M. C. 566, f. 1.				Ibid. Ibid.
——— imbricatum	LVII. 23 a. Sow. M. C. 566, f. 2.				Ibid. Ibid.
——— spinosum	LVII. 24 to 27. Sow. M. C. 566, f. 4.				Ibid. Ibid.
——— breve	Sow. M. C. 566. f. 3.				Ibid.
Terebra Hennahii	LVII. 22. Sow. Ency. Metrop. Geol. p. 578				Ibid.
——— nexilis	LIV. 17.		Petherwin.		
Bellerophon globatus	LIII. 30. Silur. Syst. 3, f. 15.		Marwood.		
Clymenia lævigata	LIV. 19. (Planulites lævigatus, Münster)		Petherwin.		
——— linearis	LIV. 19 a. (Endœophonites carinatus & E. minutus Ansted.)		Ibid.		
Goniatites carbonarius	LII. 8, 9.	nr Barnstaple.			
——— vinctum	LIV. 18. (G. Henslowi, p. 693.)	Ibid.			
Orthoceras cylindricum	LII, 6, 7.				
——— striatulum	LIV. 20.		Petherwin.		
——— cylindraceum?	LVIII. 28.				Newton Bushel.
——— Tubicinella	LVIII. 29.				Ibid. Plymouth.
Brontes flabellifer	Goldf. Act. Acad. Cæs. Leop. Nat. Cur. XIX. Pl. XXXIII. f. 3.				Ibid.
Calymene			Barnstaple.		

XLIV.—*On some Species of Orthocerata.*

By CHARLES STOKES, Esq., F.G.S.

PLATES LIX. and LX.

[Read June 6th, 1837.]

SINCE the publication of Dr. Bigsby's paper on the geography and geology of Lake Huron, in the first volume of the 2nd series of this Society's Transactions, in which some Orthocerata of peculiar forms are described, I have seen and examined many specimens of that tribe of fossils from the same place and from different parts of North America, as well as from other localities.

Many of the American specimens of which I am about to speak derive additional interest from the circumstances under which they were collected during the expeditions of discovery by Sir John Franklin, Sir Edward Parry, Dr. Richardson, the late Capt. Lyon and Capt. Back, and by Capt. Bayfield, during his survey of the Lakes and the river St. Lawrence. The correspondence in character of some of these Orthocerata with those of Lake Huron has been slightly alluded to in the appendices to Sir John Franklin's second journey and the Journal of Capt. Back, but I have thought it desirable to lay before the Society a more detailed account of them, with figures of some of the different species.

It will be observed, that these American localities are widely separated from each other, and are not parts of a continuous deposit; but the agreement in character of the limestone rock and of the fossils shows that they are of the same geological age.

For general remarks on the geology of these rocks, I beg to refer to the appendices to the naratives of the expeditions above-mentioned. The object of the present communication is to describe some species which indicate generic separations among the Orthocerata, and to call attention to some considerations respecting the relations of the shells to the animals to which they belonged.

In the species of Orthoceras found at Thessalon Island, the peculiarity con-

sists in the structure of the siphuncle, which had, I believe, never been noticed till it was described in Dr. Bigsby's paper.

The siphuncle is large in proportion to the shell, and has a tube which runs through its whole length, setting off radii in verticillations from the outside of the tube to the inner wall of the siphuncle. These verticillations correspond in number to the chambers of the shell.

The late Capt. Lyon collected at Igloolik, where the expedition under Sir Edward Parry passed the winter of 1822–23, some Orthocerata which present a similar large-sized siphuncle and a small internal tube, but no traces of the radii connecting the tube with the walls of the siphuncle can be seen. In these, however, the condition of the specimens, in which the siphuncle is filled with crystals of carbonate of lime, prevents a positive conclusion that the radii did not exist. Similar ones were found by Capt. Nias at Ooglit.

Among the specimens brought by Dr. Richardson from Lake Winipeg were some fragments of Orthocerata which exhibited a tube within a similarly large siphuncle, but the specimens were not sufficiently perfect for description, and additional information was the more requisite because this inner tube was surrounded by numerous radiating plates which filled up the remainder of the siphuncle. Other specimens of different sizes so much resembled the siphuncles of the preceding, that it was not possible to doubt their identity of character, although no traces of septa were visible; and at the same time they presented so much agreement in structure with the fossils found at Drummond Island in Lake Huron, which I described in Dr. Bigsby's paper as corals, under the name of Huroniæ, as to lead to a belief that the latter also were siphuncles of Orthocerata which had been entirely separated from the septa and external shell. To clear up, if possible, a point so interesting to those who study fossils was most desirable, and when Capt. Back was about to undertake the expedition in search of Capt. Ross's party in 1832, Dr. Richardson furnished him with a memorandum of the particular locality of Lake Winipeg, in which the fossils were found, with a request that he would seek for better specimens.

Capt. Back succeeded in obtaining some which have added much to our knowledge of the subject, and with further evidence which will be presently noticed, I think that the connexion of all these bodies with the family of Orthocerata is established.

In the month of March last, Capt. Dawson, R.E., called my attention to a large specimen of an Orthoceras found at Castle Espie, in the county of Down, in Ireland, by Mr. Frederick W. Simms. On examination, I found in it the same peculiarities of the tube within the siphuncle, and radii from the tube,

as in the species of Thessalon Island; and this is the first instance of this plan of organization I have met with in an Irish or English specimen.

As all these specimens agree in the peculiarity of the siphuncle possessing an interior tube, and as this tube had doubtless an important function, I am disposed to include them all in one genus; and that I may not multiply names without necessity, I will adopt the generic name of Actinoceras, given to the species from Thessalon Island by Bronn in the Lethæa Geognostica, where he copies the figure from the Geological Society's Transactions, which figure appears to be his only authority for establishing the genus*.

It is true that the radii surrounding the tube within the siphon are not at all detected in some of the species, and that the radiating lamellæ of others present a very different appearance from the separate radii of the species from Thessalon Island, but the important peculiarity of a tube within the siphon induces me to include them in one genus, as a subdivision of the family of the Orthocerata. More accurate knowledge may be acquired and the arrangement now proposed may be improved, but in the mean time it will, I think, be advantageous to adopt this character as a basis for making one group of these interesting fossils. The name is not characteristic of all the species thus brought together, but at present I had rather retain one that has been published than introduce a new one.

The character of the genus Actinoceras is a large siphuncle, much dilated in each chamber and contracted at the parts where the septa are attached to it. Within the siphuncle a continuous tube, which appears to have been capable of expansion or contraction, and (sometimes at least) furnished with radii in verticillations which connect the tube within the walls of the siphuncle.

The specimens I am yet acquainted with, appear to resolve themselves into the following species :—

1. *Actinoceras Lyonii.* (Pl. LIX., fig. 1.)

In this species a small tube is seen within the siphuncle, but no radii have been traced from it. The exterior has not been seen, and the specimens are not sufficiently perfect to lead to a decided opinion on this point. The shell is conical, tapering gradually. Found at Igloolik and Ooglit, in a yellowish-white limestone.

2. *Actinoceras Bigsbii.* (Geol. Trans., vol. i. N.S., Pl. XXV.)

The tube larger than in the preceding, and the radii in distinct verticillations. Found at Thessalon Island, Lake Huron. It may be doubted whether all the specimens belong to one species.

* However desirable it may be to give names to fossils in order to facilitate references, I think the attempt to establish and name genera from no other materials than figures published by other persons, is likely to lead to much evil. In the present instance Herr Bronn concludes his generic description with the words, that it requires further confirmation.

In those figured in the Geological Transactions, vol. i., 2nd series, Pl. XXV., it will be seen that the general form of the shell diminishes more rapidly in size, and that the siphuncle is perhaps nearer to the side in fig. 3 than in fig. 1. In all these specimens the septa are not preserved, but there is a vacant space between each chamber, although the substance of the walls of the siphuncle are distinctly seen. The substance of these septa must have been of considerable thickness, and on breaking a specimen for the purpose of examination, I found that a layer of shell belonging to the septa was visible on the cast of each of the chambers they had divided. From this it appears that the septa are composed of several layers.

3. *Actinoceras Richardsoni.* (Pl. LIX., fig. 2, 3.)

In this the tube is small; it is surrounded by numerous laminæ or plates, filling up the siphuncle; but it is difficult to determine their nature.

The external shell is slightly conical in form. From Lake Winipeg, in yellowish-white limestone much resembling that from Igloolik.

4. *Actinoceras Simmsii.* (Pl. LIX., fig. 4.)

Shell large, conical, the upper chamber very deep*. The tube within the siphuncle smaller than in *A. Bigsbii.*

The number of the radii is not yet ascertained, but appears to be much less than in *A. Bigsbii.* This is a very large species found by Mr. Frederick William Simms, in a lime-quarry at Castle Espie, in the county of Down, in Ireland. It is two feet long, though imperfect, and contains the siphuncle only in the lower portion of the specimen, being broken away in the other part. The septa are composed of several laminæ, and are of considerable thickness, showing a structure similar to that described by Mr. Miller in the chambered part of the Belemnite, but which he considered peculiar to that genus and not to exist in Orthocerata†.

Of specimens belonging to other divisions of the Orthoceratidæ, one from Drummond Island, presented to me by Capt. Bayfield, R.N., is a most beautiful and instructive example of the separation of a siliceous fossil from its surrounding rock by the long-continued action of weather.

It exhibits an entirely new arrangement of the siphuncle, which could not be shown in the external view of this part, but which is well laid open in this fractured specimen.

The structure thus seen has led to the explanation of peculiarities in the siphuncle of several specimens which were previously unintelligible, and hence to the establishment of another genus in the family, founded, as in the preceding case, upon the structure of this part of the shell.

* I have noticed this circumstance here because it is very remarkable in this specimen, although I believe that the upper is always deep in Orthocerata when perfect. In this instance it is however deeper than in any other I have seen. This figure is one-third of the natural size.

† This specimen is remarkable for having the external surface of the shell covered to a considerable thickness with a small species of coral, which must have continued for a long time to grow upon the shell, evidently after the death of the animal. This will be referred to in a subsequent part of his communication, p. 710.

The interior of the siphuncle in these specimens is not continuous, but is divided into separate portions, corresponding in number with the chambers. The exterior shell of the siphuncle is extremely thin, and is generally broken away where it has been exposed to the weather; and the interior portions of the siphuncle are seen. A deep indentation in the middle of each of these portions corresponds with each septum of the shell, so that of each of these interior portions of the siphuncle one half is placed in one chamber and the other half in the chamber below it. A longitudinal section of it exhibits a very curious arrangement: the opening or interior passage of the siphuncle is comparatively small, and the inner and outer lines of each portion shown by the section are beautifully curved, as shown in Pl. LX., fig. 1. The space between the inner and outer walls of these portions is considerable, and there is no trace of its having been filled by any substance.

Induced by the information afforded by this specimen, I made sections of others in which I have detected the same construction, and by this means arrived at the knowledge of the external thin shell which originally covered the siphuncle. The siphuncle thus formed, has some resemblance to a row of beads, and hence the name of Ormoceras * has been chosen for a group or genus to include them.

As yet I can attempt to distinguish only three species, all of which are from the same locality, Drummond Island in Lake Huron :

1. *Ormoceras Bayfieldi.* (Pl. XL., fig. 1.)

Shell slightly conical. The laminæ of the septa separate from each other on one side of the shell so as to show a space between them. This will be afterwards noticed.

2. *Ormoceras Backii.* (Geol. Trans., 2nd Series, vol. i., Pl. XXX., fig. 1.)

Siphuncle larger than the preceding. This species a good deal resembles the figure in Plate VI. of Breyneus, Dissertatio de Polythalamiis.

3. *Ormoceras Whitei.* (Geol. Trans., 2nd Series, vol. i., Pl. XXX., fig. 2.)

Named after M. White, Esq., of the Army Medical Staff, who was stationed on Drummond Island, and collected this and many other specimens of these interesting fossils.

In speaking of *Actinoceras Richardsoni,* from Lake Winipeg, I pointed out the resemblance of its siphuncle to the Huroniæ, which I formerly considered to be corals, and described as such in Dr. Bigsby's paper. I was led to that opinion by the radiating plates, for which I knew of no analogy except in similarly radiating lamellæ of the madreporic corals. I did not at that time understand the peculiar structure of the centre of these corals, in which

* From Ὄρμος monile, and κέρας cornu.

I have since observed, that the hard parts are peculiarly contorted, generally in a spiral manner, for the purpose of giving a stronger attachment to the base of the animal's stomach, as is described in the Zoological Journal, vol. iii. p. 486.

The centre of the Huroniæ is different from this, as in a longitudinal section an opening or tube is seen to pass continuously through the whole length.

Other specimens, which could not be separated in character from the siphuncle of the *Actinoceras Richardsoni* from Lake Winipeg, but on which no traces of septa, or external shell, could be perceived, had, as before observed, so much resemblance to the Huroniæ, as to lead to the conclusion that the latter also were siphuncles of Orthocerata; but if so, we have to account for the constant disappearance, in the Huroniæ, of all traces of the septa and of the external shell.

This extraordinary fact seems to be intelligible only on the supposition that these parts were extremely thin, or composed of a substance not sufficiently strong to be permanent after the death of the animal. A strong corroboration of this suggestion is furnished by a specimen from Drummond Island, given to me by my friend Captain Portlock, R. E., President of the Geological Society of Dublin. A very careful drawing of this specimen is given in Pl. LX., fig. 5. The lines on this specimen, it cannot, I think, be doubted, indicate the septa and external shell of an Orthoceras, while enough of the siphuncle is seen to establish its connexion with the Huroniæ. These lines show that the substance of the external shell and of the septa must have been so thin that it is not a matter of surprise that they have been very rarely preserved.

To this specimen I have given the name of *Huronia Portlockii,* as I do not at present propose to alter the name of the genus.

To add to the evidence on this subject, I caused longitudinal sections to be made of some specimens of Huroniæ, two of which are represented in Pl. LX., fig. 2 and 3. They are of different forms, approaching to the *H. vertebralis* and *H. spheroidalis* of Dr. Bigsby's paper before quoted. These fossils are not in the most favourable state of preservation for giving clear evidence of their original structure: the calcedony and quartz, which has crystallized upon it, tend much to make it obscure. Notwithstanding this, there is to be traced a great resemblance to the structure of the interior of the siphuncle of the Ormoceras; in each of them may be observed parts so greatly resembling the beautifully curved portions figured in *O. Bayfieldii,* and so constantly to be traced in each enlarged portion of the fossil, that it seems evident that they indicate the original structure.

If, then, these Huroniæ are to be considered as the siphuncles of Orthocerata, (and such is the conclusion I have adopted from the evidence just stated,) and the septa and external shell were so thin and slight, in comparison to the strength and substance of the siphuncle, it becomes an object of interest to consider what was the condition of the shell in regard to the animal in its living state.

It was, I believe, first suggested by the late Mr. Miller, "that all chambered shells were inclosed in, or capable of being covered and encompassed by, the animal; for without such a contrivance, that nice degree of buoyancy which they are intended to furnish to the animal, would be destroyed by the adhesion of parasitic testacea*."

Although we cannot positively pronounce that such was the fact, the peculiar thinness of the septa and external shell, described in the specimen of *Huronia Portlockii* just mentioned, appear to me to require that they should be inclosed and protected. If the animals were contained in the upper chamber only, the lower ones would be exposed to a great extent in length; and from the size of some of the specimens of Huroniæ, we must suppose the animal to have been of considerable weight; and a corresponding strength would be required for the preservation of the shell from destruction if it were external.

It is true that in Carinaria and Argonauta we have examples of very thin external shells, and in the latter genus, some are of considerable size; but in these instances the animal fills the whole shell; consequently it is not exposed to the same degree of danger of injury as would be a long external appendage to an Orthoceras. In Nautilus the animal inhabits its last chamber only; and the shell of the earlier chambers is exposed; but the shell is of considerable strength, and, being convoluted, every part of its surface is within reach of the soft parts of the animal, which would protect it from the adhesion of parasites.

Whether all the straight-chambered shells were inclosed or not, and what evidence can be obtained upon the subject, is consequently an object of inquiry; and in this point of view I have paid attention to the Baculite. The external shell of these fossils is very rarely preserved; but I have met with some specimens which show that it must have been so thin that it could afford to the lower chambers little or no protection from external violence; and it is difficult to imagine that shells of this form and size would be free from danger if external and thin in substance.

Wherever I have seen the last chamber of Orthocerata well preserved, I

* Geological Transactions, 2nd Series, vol. ii. p. 58.

have found that it is of considerable length, and that it gradually diminishes in thickness to the upper termination, where it is so thin that it probably was never exposed.

When speaking of *Actinoceras Simmsii*, I have mentioned that a beautiful coral with small cells, resembling the Favosites, covers it, and which shows the growth of a long period; there being many concentric layers accumulated on the shell. This is the only instance I know of the occurrence of coral or shell attached to an Orthoceras; and the rarity of such cases may fairly be stated as a further argument to prove that the Orthocerata were protected from the adhesion of parasites. In this instance, indeed, there is evidence of the growth of the coral being subsequent to the death of the shell; for a portion of the coral is covered with earthy deposit, over which other layers of the coral have afterwards grown*, as shown in the section, Pl. LIX., fig. 5.

It has long been my wish to attempt a general revision of the Orthoceratidæ, with the view of arranging all the fossils of this family, and dividing them into groups; but the subject is very extensive, the difficulty attending the investigation is great, and my avocations allow me but little time to devote to it. I have thought it better to limit myself to the preceding observations, and leave them to the test of examination by other observers. I wish, however, to point out another peculiarity in the structure of Orthocerata, which is to be found in the septa of the chambers. The accompanying representation, Pl. LX., fig. 4, of one from Russia, is the best example I have met with. The laminæ of the septa in these cases appear to separate, and leave a considerable space between them; on one side of the chamber the line of the upper lamina is peculiarly curved, and seems to follow a regular law, as the form is similar in each septum.

I cannot at present say, if this peculiarity is confined to a particular division of the Orthocerata. The Russian specimen may probably belong to the division Ormoceras, which has the siphuncle divided into portions. This is not positive; but the same peculiarity is seen in *Ormoceras Bayfieldii* and *O. Whitei*. I have also observed a nearly similar arrangement in Lituolite. It must be noticed, however, that as this separation of the laminæ of the septa is only on one side of the shell, consequently our knowledge of this peculiar structure is only to be obtained from the sections laid open by accidental fracture, or by those made artificially, and mostly for other purposes than the ascertaining of this point.

* Since this paper was communicated to the Society, Mr. S. Stuchbury has communicated to me another example in the collection of the Bristol Institution of similar coral surrounding an Orthoceras.

A considerable difficulty exists in the examination of these fossils in many cases, particularly in those where the substance of the fossil is replaced by silex. A fracture, or a section by art, does not so clearly show the structure of the fossil, as its exposure by the slow action of the weather; and hence we greatly depend on accident for obtaining our information.

In other cases, the substance of the shell is entirely wanting, and vacant spaces alone represent the form of the fossil. This has been noticed in the *Actinoceras Bigsbii* from Thessalon Island; and the same thing is constant in regard to the septa of Baculites found at Maestricht. It may perhaps be worth consideration, whether the nature of the substance of which these parts of the animal was composed, has much influence on the preservation or non-preservation of them in the fossil state; and I would suggest that it is always worthy of observation, what is the condition of the greater number of other fossils found in the same rock. In the case of Maestricht, we find some shells and corals and the crusts of crabs preserved; but the septa of Baculites are always wanting, although sometimes we can find traces of their thin external shell. I notice this, however, merely for the purpose of exciting observation, because I am not aware if it has ever been made a subject of inquiry.

If, from what has here been stated, it shall appear probable that the Huroniæ are the remains of Orthocerata, and that the shelly part of some of the animals of this family was so thin as to have been generally destroyed, we shall be led to the belief that the fossils figured in Dr. Bigsby's paper, at Pl. XXX. of Vol. i. Geol. Trans., 2d. Series, also belong to Orthocerata; and though there is not evidence to establish conclusive proof that they were so, yet the conjecture becomes more probable, from our inability to associate these remains with any other known organic structure.

These would open to us a great variety of forms for the animals of the Orthoceratidæ, in addition to those indicated by the different forms of the decidedly chambered shells with siphuncles, which are found in the older rocks, of which there are many undescribed kinds, and which have always been attributed to this family.

We find these remains sometimes of conical shape, tapering rapidly; sometimes curved, and at other times of great length, and tapering very gradually. The animals to which they belonged were, no doubt, the Carnivora of the ancient seas, in the mud of which their remains have been preserved, along with those of contemporaneous animals of species on which they preyed; and it is of some interest to imagine an abundant variety in their forms as great as was that of the Saurians of a later period, when that race of gigantic devourers was called into existence.

It may be asked, why we do not find rhyncholites in these older rocks? but I do not feel the objection to be of much importance, when I consider the comparative rarity of those fossils in the rocks in which the Ammonites are so numerous.

It will not be doubted that these chambered shells belonged to the carnivorous race of Cephalopods: we know of no other remains in these older rocks which can be attributed to carnivorous marine animals, except some few fishes; and it is quite in unison with the other observations that have been made in the natural history of organic remains, to find a great variety of forms of this family existing at one period, when they were the chief agents in performing the duties allotted to the marine Carnivora, and to find that their representatives in this family were subsequently confined to the forms of Ammonites and Belemnites, when other creatures, such as the Saurians, were created to take a part in the important task assigned to them. A similar change is the appearance of carnivorous Trachelopods at a later period, on which subject are some good observations first pointed out in a paper by Mr. Dillwyn, in the Philosophical Transactions for 1823.

XLV. *A Notice respecting some Fossils collected in Cutch, by Capt. Walter Smee, of the Bombay Army.*

By Lieut. Colonel W. H. SYKES, F.R.S., F.G.S.*

[Read March 26th, 1834.]

Plate LXI.

In exhibiting to the Geological Society some interesting fossil shells, collected in Cutch by Capt. Smee, of the Bombay army, I have to make my acknowledgements to Mr. James de Carle Sowerby for his assistance in determining the various specimens. The locality from which they were obtained is in the province of Choorwaugur, between the 23rd and 24th parallels of north latitude, and the 70th and 71st degrees of east longitude. On the east and north it is bounded by the celebrated Runn, a tract of low lands, one part of which is periodically overflowed, another is salt marsh, and a third sandy desert; and, extending from the mouths of the Indus to the head of the Gulf of Cutch, it gives the country an insular character.

I shall confine the notice to a few short remarks on the specimens.

Of *Ammonites* there are several species, and one of them bears so close a resemblance to *A. Harveyii* of the oolitic series of England, that Mr. Sowerby cannot satisfy himself that there is any difference (see fig. 1, wood-cut, p. 719). The new species are figured in Plate LXI. The whole of the specimens were obtained from the red rock in the neighbourhood of Shahpoor and Kuntkote.

Trigonia. Imbedded in the mouth of *Ammonites Harveyii* (woodcut, fig. 1, p. 719), is apparently a young specimen of *Trigonia costata,* a shell characteristic of the oolitic rocks of England†. Another species which Mr.

* This paper was read previously to that by Capt. Grant on Cutch, printed in the second part of the volume, and the delay in its publication has been owing to various causes which it is unnecessary to state.

† A full-grown shell of this species is given in Pl. XXI. fig. 16, of the illustrations to Capt. Grant's Memoir.

Sowerby considers to be new, I have named after Capt. Smee. It occurs in the water-courses and the ploughed fields about Shahpoor, but the specimens do not appear to have been water-worn. (See Pl. LXI. fig. 5.)

Astarte. Of this genus Mr. Sowerby has determined two new species. They were met with under similar circumstances to the *Trigoniæ*. (fig. 1 & 2.)

Corbula. An undescribed species occurs abundantly in an indurated ferruginous rock at Dookurwarra in the Runn, at the north-east point of Cutch, in the 71st degree of longitude. The strata are highly-inclined and very thin, and transverse sections of the slabs present a beautiful appearance. It is not associated with the other shells.

Gryphæa. A specimen belonging to this genus so closely resembles the *Gryphæa dilatata* of the Oxford clay of England, that Mr. Sowerby has not been able to separate specifically the Cutch fossil from it. (See wood-cut, fig. 2.) Other specimens, varieties apparently of this shell, occur in Capt. Smee's collection, and differ in the back of the lower valves being more convex and the beak more prominent. They were all found under the same circumstances as the *Trigoniæ*.

Capt. Smee's series also contains specimens of *Lycophrys**, presented to him by Dr. Burnes of the Booj Residency. They are said to be thrown up in ridges near Luckput Bunder. In addition to the shells, the collection includes fragments of silicified fossil wood, and radiated iron pyrites similar to that contained in the chalk of England.

I have also to point out to the Society specimens of alabaster and a hard and durable oolite from my own collection; the former from Cutch, and the latter from near Poorbunder on the west coast of the peninsula of Goojrat. This rock would appear to characterize the major part of the western portion of the province, as it is found abundantly at Raujcote in the centre of the peninsula. The oolite is used in that magnificent structure the town-hall of Bombay. It does not appear to resemble exactly any of the characteristic oolites of England.

Lignite. I close the catalogue with a specimen of lignite from Cutch. Attempts were made by the government to work this coal; but whether from mismanagement or from other causes, they were not persevered in, and I believe the beds at present lie undisturbed. The locality is at the village of Tramboa, from 6 to 8 miles north of Booj. Traces of coal are also met with in many other places.

As the tracts whence the above specimens came have not been visited by a geologist, it may scarcely be prudent to speculate on the age of the forma-

* See Pl. XXIV. fig. 15 and 16, of Capt. Grant's illustrations.

tion to which they belong. If generalizations in geology in Europe be subject to exceptions, we shall run no small risk in applying European analogies to India; where we find coal occurring without the carboniferous series—a total absence of the cretaceous formation, and trap occupying whole regions without the intervention of any sedimentary rock, and without the appearance of modern or even ancient volcanos. Were we to judge of the N.W. coast of India in the neighbourhood of the localities of the above specimens, from its general flatness, its salt marshes, and the extent of the Runn, we might consider it as recently emerged from the ocean, and comparatively modern fossil shells might have been looked for. The inhabitants, indeed, consider the surface of inland water as gradually contracting, and the period may arrive when the Runn shall disappear. If English analogues be our guide, the fossil specimens I have submitted to the Society would seem to belong to the secondary rocks; *Ammonites, Trigoniæ, and Gryphæa* have been found only in formations below the tertiary systems,—we may not therefore err in considering the formations of Cutch to be secondary. Quarries of fine crystallized marble are found at Nuggur Parker on the north bank of the Runn.

The strata of Cutch have been much disturbed by the intrusion of igneous rocks, which in fact are the highest in the country, and it is still subject to earthquakes. The country furnishes an abundant supply of iron ore. It is much to be regretted that the East India Company have not deputed a scientific person to examine Cutch and Goojrat, as the cost of the undertaking would very probably be amply repaid by the discovery of their mineral treasures; and a yet higher advantage would be obtained in the light which would be thrown on the history of the earth*.

Note.—November 4th, 1837.

When the specimens alluded to in the preceding notice were first submitted to the examination of the Society, the unexpected resemblance which some of them were found to bear to English oolitic fossils, gave rise to doubts whether English shells had not accidentally got into Capt. Smee's collection. To clear up these doubts, I wrote to my friend Colonel Pottinger†, the British Minister in Cutch, to collect for me, far and wide, all the organic remains to be met with. Colonel Pottinger, with that zeal which always characterizes

* This wish has been to a very great extent fulfilled by the labours of Capt. Grant, 1839.

† Now Sir Henry Pottinger, Bart.

his prosecution of useful objects, so effectually realized my wishes, that in a comparatively short time, a large collection of fossils reached me in England; a series of these I presented to the Society, and on examination, the genuineness of Captain Smee's fossils was fully established from identical species being met with in the collection. Shortly afterwards, Capt. Grant, of the Bombay Engineers, arrived from Cutch,—rich in a collection of fossils, rich in a local knowledge of the country, and doubly rich in his powers of graphic delineation. His treasures and memoranda were submitted to the Society, and I thought no more of mine. It appears, however, that independently of there being some few specimens in my collection from the field of Capt. Grant's researches which he does not possess, a series of my shells comes from a territory not geologically investigated by Capt. Grant, namely, the desert N.E. of Cutch, from Balmeer and Joonah, and the plains and rivers in their neighbourhood, and proved by the specimens collected by Col. Pottinger to belong to the same series of beds as those from which Capt. Smee's and Col. Pottinger's specimens were obtained in Cutch. Under these circumstances it has been thought desirable to figure the new specimens from Cutch and the Desert; and the present notice may be looked upon as an appendix to my former memoranda on Capt. Smee's fossils.

W. H. Sykes.

List of Fossils contained in the collections of Capt. Smee and Col. Pottinger, determined by Mr. James de Carle Sowerby. (Plates XXII. to XXV. accompany Capt. Grant's Memoir, see *ante*, p. 289.)

Genus and Species.	Reference.	Locality.
Lycophrys dispansas, Capt. Grant's Mem.	XXIV. f. 16.	Near Luckput Bunder*.
Corbula pectinata	LXI. f. 4, 4 a.	Dookenarra, in the Runn*.
Astarte major	LXI. f. 1.	In the neighbourhood of Shahpoor*.
——— compressa	LXI. f. 2.	
——— rotunda	LXI. f. 3, 3 a.	Hills 12 to 15 miles north of Booj†.
Trigonia costata, Min. Con. LXXXV..	Woodcut fig. 1.	Ibid†.
——— Smeeii	LXI. f. 5.	Shahpoor*.
Cucullæa virgata, Capt. Grant's Mem..	XXII. f. 1, 2‡.	Hills 12 to 15 miles north of Booj†.
Nucula tenuistriata, Capt. Grant's Mem.	XXII. f. 3.	Ibid†.
Plicatula pectinoides, M. C. CCCCIX..	XXII. f. 6, 9 a.	Ibid.†; also Desert to the N.E. of Cutch.
Ostrea orbicularis, Capt. Grant's Mem.	XXIV. f. 8.	Hills 12 to 15 miles north of Booj†.
——— flabellulum, Min. Con. CCLIII.	XXV. f. 8.	Ibid†.
Ostrea carinata? Min. Con. CCCLXV.	XXII. f. 8.	Ibid†.
——— Marshii? Min. Con. XLVIII.	XXII. f. 9.	Ibid†.

* From Capt. Smee's collection. † From Col. Pottinger's collection.

‡ *C. virgata*, a young specimen, is represented in Pl. LXI. f. 6.

Genus and Species.	Reference.	Locality.
Gryphœa dilatata, Min. Con.	Woodcut, *infra*, fig. 2.	In the neighbourhood of Shahpoor*.
Terebratula dimidiata, Min.Con.XV.f.8.	XXII. f. 15.	Hills 12 to 15 miles north of Booj; also from the Desert to the N.E. of Cutch†.
——————— microrhyncha ..	LXI. f. 7.	Hills 12 to 15 miles north of Booj†.
Fragments of a thick fibrous shell	———	
Tornatella striata.....	LXI. f. 6, 6 a.	Hills 12 to 15 miles north of Booj†.
Belemnites (fragments)	———	Desert N.E. of Cutch†.
Ammonites Harveyii, Min. Con. CXCV.	XXIII. f. 5. Woodcut, *infra*, fig. 1.	Hills 12 to 15 miles north of Booj†. Shahpoor or Kuntcote*.
——— Maya	LXI. f. 8.	Ibid*.
——— calvus	LXI. f. 9.	Ibid*.
——— Pottingerii	LXI. f. 10.	Desert N.E. of Cutch†.
——— fissus	LXI. f. 11.	Ibid†.
——— torquatus	LXI. f. 12.	Desert N.E. of Cutch†.
——— fornix	LXI. f. 13.	Hills 12 to 15 miles north of Booj†.
Nummulites exponens	XLI. f. 14 a. to e.	Luckput Bunder.
Fasciolites elliptica	XXIV. f. 17.	Ibid*.

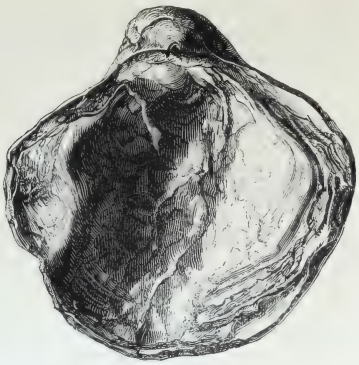
* From Capt. Smee's collection.

† From Col. Pottinger's collection.

Fig. 1.

Ammonites Harveyii.

Fig. 2.



Gryphœa dilatata.

XLVI. *Notes on the Age of the Limestones of South Devonshire.*

By WILLIAM LONSDALE, F.G.S.

[Read March 25, 1840.]*

THE reasons which induced me to assume on zoological evidence, that the limestones of Southern Devon, between Dartmoor and the coast, would prove to be of the age of the old red sandstone, not having been placed on record in a separate form, Mr. Murchison has begged me to lay before the Society a distinct notice of my claim to having been the first to propose the classification recently put forth by Professor Sedgwick and himself; and in consequence of an extension of those views to Belgium and the Boulonnais, Dr. Fitton has urged me to comply with the request. In the memoirs† in which Professor Sedgwick and Mr. Murchison announced the change in their classification of the older sedimentary strata of Devonshire and Cornwall, the clearest and amplest acknowledgements are made of my share in promoting the alteration; but as it is possible that some mistake may hereafter arise, relative to the nature and limits of my suggestion, I conceive it is a duty to others as well as to myself to comply with the above request. I regret, however, that I cannot make this notice as satisfactory as I could wish, from the whole of the data not being accessible; and I regret that my official duties have prevented me from bestowing upon it that time and thought and research which ought to be evident in the shortest communications read to this Society.

Before I state the nature of my claim, I consider myself called upon to give, as far as I am able, a brief summary of the opinions previously entertained by geologists respecting the age of the South Devon limestones, that the proportionate amount of priority of claim may be duly estimated.

Woodward (1729) and Da Costa (1757) notice the Plymouth marbles, but only as mineral substances; (Woodward's Catalogue, vol. i. p. 20, xb. 4; vol. ii. p. 66, b. 18–21. Da Costa, History of Fossils, p. 206.)

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* This communication is printed out of its regular order by direction of the Council, in consequence of the subject to which it refers being connected with the Memoir of Professor Sedgwick and Mr. Murchison on Devonshire.

† Lond. and Edin. Phil. Mag., April 1839; *antè*, p. 688, *et seq.*

Maton notices the South Devon limestones and places those on the eastern side of the Tavey in argillaceous slate; but in his geological map the same character is employed for the Devonshire limestones, the mountain limestone and the oolitic series. (Tour through the Western Counties, vol. i. pp. 121, 289, 290, 1797.)

Playfair notices a bivalve shell which he found in a loose specimen of schistose micaceous limestone opposite Stonehouse; and he adds, there are certainly no rocks more decidedly primary than those which surround Plymouth. He considered the limestones of Berry Head to be of the same age. (Illustrations of the Huttonian Theory, note iv. p. 164, 1802, French Translation, p. 54, note.)

In 1809, Dr. Berger and M. Louis Albert Necker made their joint examination of Devonshire and Cornwall; and they both considered the limestones to be transition. They observed no organic remains. (Dr. Berger, Geol. Trans., 1st Series, vol. i., p. 103. 1811. Necker, MS. Catal.)

De Luc mentions frequently the Plymouth, Chudleigh, and other limestones of Southern Devon; and describing a quarry near Sequer's Bridge, he says, "The strata much resemble the most ancient secondary limestones of the Alps, which contain but very few marine bodies." He observed none in that quarry. (Geol. Travels in England, vol. ii. p. 342; see also Index to vol. xi. 1811.)

Dr. Thomas Thomson assigned the Plymouth limestones to the transition class. He sought likewise carefully for fossils, but equally without success. (Ann. of Phil., vol. ii. p. 248, 1813.)

Dr. Kidd placed the Devonshire marbles in the transition limestones of Werner, including in them the mountain-limestone. (Geological Essay, pp. 93, 94, 1815.)

In Mr. William Smith's map of England (1815), the limestones are coloured as portions of the transition series.

Mr. Brande, in his Outlines, considers the Plymouth calcareous rocks as mountain-limestone, and states that they rest immediately upon slate. (Outlines of Geol. p. 90, 1817.)

The late Mr. W. Phillips assigned them to the transition series. (Outlines, 1st edit. p. 210, 1816; Selection of Facts, p. 162, 1818.)

In Mr. Hennah's first notices on the organic remains of the Plymouth rocks, the age of the strata is not defined; but it is impossible to pass over the first communications of a geologist to whose labours we are indebted for a large share of that evidence by which the classification of the Devonshire formations will be decided. (Geol. Trans., 1st Series, vol. iv. p. 410, 1817.)

In Mr. Greenough's First Principles of Geology, (p. 219) published in 1819, the Plymouth calcareous rocks are noticed as examples of mountain limestone, resting immediately upon slate, to the exclusion of the old red sandstone; but in the first edition of his geological map (1820) the whole of the South Devon limestones are coloured as belonging to the greywacke series.

In a memoir on Cornwall, Professor Sedgwick, in alluding to Mr. Hennah's collection of organic remains, states his belief that the fossils cannot be identified with those of the mountain-limestone; and he adds, "It would introduce great confusion not to separate the limestones of Devonshire from the great metalliferous limestones." (Trans. Phil. Soc. Cambridge, vol. i. p. 142, 1820, 1821.)

The Rev. W. Conybeare, in his Outlines (p. 353, 1822), and in his memoir on the mountain chains of Europe, (Ann. Phil., vol. xxi. p. 7, 1823) and Dr. Buckland in his description of the caves at Oreston and the fissures at Chudleigh (*Reliquiæ Dil.*, p. 59, note é. 1823), consider the South Devon limestones as transition.

The Rev. J. J. Conybeare assigned the dark limestones to his "superior slate," and the coral limestones to his "sand slate" division. (Ann. Phil. 1823, vol. xxi. p. 185.)

MM. Dufrénoy and Elie de Beaumont, who visited England in 1823, place them in the greywacke series. (*Voy. Métal.* p. 11, 1824.)

About the year 1824, Mr. Hennah published his account of the limestone rocks of Plymouth; and considered them, on account of the abundance of their organic remains, to be "among the

mountain-limestones, and of an ancient rather than a recent date": the fossils of Torquay, Petit Tor, and the surrounding neighbourhood, are said to be for the most part similar. (pp. 38, 63.)

Mr. De la Beche, in a Memoir on Tor and Babacombe Bays, states that the limestones rest upon old red sandstone, and contain fossils which have been discovered in the carboniferous limestone of other places. (Geol. Trans., 2nd Series, vol. iii. p. 163.)

In the Transactions of the Plymouth Institution, is a paper by Mr. Prideaux, containing the following passage; "Catdown and Teats' Hill are entirely limestone, which very soon after parting from the slate assumes a reddish hue, from the presence of siliceous matter of that colour; this presently after appears in bulk in the character of the old red sandstone, alternating with the limestone, south, though much less strikingly than the slate does northward." Mr. Prideaux also observes, There is a marked diversity in the texture, position, and contained animal reliques of the limestones, and that the eastern is probably older than the western; referred by Mr. De la Beche to the carboniferous series. (Trans. Plym. Instit. pp. 36 and 43, 1828–1830.)

Dr. Boase, in his elaborate Memoir on the Geology of Cornwall (1830–1831), speaks doubtingly of the age of the limestone on the west side of Plymouth Harbour, not having been able to determine its connection with the greywacke. The strata of Cawsand Bay he states is generally believed to be old red sandstone. (Trans. Geol. Soc. Cornwall, vol. iv. pp. 216, 218.)

In all the editions of Mr. De la Beche's Manual (1831 to 1833), the limestones on the southern side of Tor Bay are included in the greywacke series; but the author considers it exceedingly difficult, in consequence of the greywacke sometimes being undistinguishable from the old red sandstone, to determine the age of those limestones of Southern Devonshire, which are much broken by faults, greatly disturbed and contorted or much concealed by the new red sandstone (1st edition, p. 438, and note, 1831; 2nd edition, p. 454, and note, 1832; 3rd edition, p. 420, and note, 1833).

About the year 1833 appeared the valuable article on Geology in the Encyclopædia Metropolitana, by Mr. J. Phillips. It contains extensive lists of organic remains, assigned to the primary (transition) class; but the author leaves to future observers to determine whether the South Devon limestones belong to the transition series (p. 574, 577).

In the two first editions of the same author's Guide (p. 115, 1834 and 1835), the sedimentary rocks of Devonshire are also placed in the primary class; and in the 3rd edition (1836), their position is not defined, it being only stated that some portion of North and South Devon belong to the Cambrian System, and that much of the killas of Cornwall is not more ancient (1st edition, p. 115; 2nd edition, p. 129; 3rd edition, p. 140).

In the abstract of a paper read in January 1836, by Mr. De la Beche, the whole of the greywacke of Devon and Cornwall is said to be older than the Silurian formations. (Geol. Proceedings, vol. ii., p. 225.)

In a Memoir on the country between the Ex and Berry Head and Dartmoor and the coast, read May 1836, Mr. Austen mentioned the transition rocks as containing beds of limestone rich in organic remains. (Geol. Proceedings, vol. ii. p. 414.)

It was at the Bristol Meeting of the British Association, August 1836, that Prof. Sedgwick and Mr. Murchison read their first memoir on the structure of Devonshire, in which they proved, for the first time, that the culm-measures of the central part of the county are newer than any of the stratified groups associated with them, and of the age of the carboniferous series; and though they did not describe the country south of Dartmoor, yet the calcareous rocks of that district were considered to be on a parallel with the lowest division of the North Devon series, or in the middle division of the Cambrian System. The same view is maintained in the paper read to this

Society in May and June, 1837. (Athenæum, 1836, p. 611, section, p. 612; Reports of British Association, vol. v., p. 93; Geol. Proceedings, vol. ii., p. 560.)

Mr. Phillips, in his work on Geology forming vols. xcvii. and cxi. of the Cabinet Cyclopedia, describing the fossils of the primary class (including the transition or greywacke series), states that "the Plymouth and South Devon shells, supposed to be identical with species of the mountain-limestone, are in general, excepting perhaps some from Newton Bushel, quite distinct, as I learn from a sight of Mr. Hennah's and other specimens" (vol. i. (xcvii.) p. 140).

In Mr. Austen's communication, read December 1837, the limestones were described as occurring in the uppermost portion of the transition or greywacke series of South Devon; but he expressed verbally his belief that they were the equivalents of the mountain-limestone; and he called attention to some fossils which he thought would bear him out. (Geol. Proc vol. ii. p. 584.) It was immediately after the reading of that paper, and partly from an examination of Mr. Austen's specimens, that I formed the opinion relative to the limestones of Devonshire being of the age of the old red sandstone; and which I afterwards suggested first to Mr. Murchison and then to Prof. Sedgwick, and at a later period, in 1838, to Mr. De la Beche and other Fellows of the Society.

Mr. Bakewell considers these calcareous formations as belonging to the lower transition limestones. (Introduction to Geol., 3rd edit., p. 136, 1838.)

Mr. De la Beche's valuable Report on Cornwall and Devonshire appeared early in 1839. In this work, the limestones, with the associated clay-slates, are placed in the greywacke group (p. 64, *et seq.*). With reference to the lists of fossils, given on the authority of Mr. James Sowerby, Mr. De la Beche says, "Organic remains have been detected, more particularly near Newton Bushel and Ogwell, among which many shells bear so great a resemblance to others detected in the true carboniferous or mountain-limestone, that at a first glance they might be considered of the same species. How far they may bear that careful scrutiny to which they will probably be subjected, remains to be seen. In the mean time, however, the near approximation to form, supposing, for the sake of argument, that it is merely a near approximation of those shells to species well known in the true carboniferous limestone, is a subject of considerable interest" (p. 75). "There is nothing in the shells found in the Plymouth limestones, which should prevent us from considering them a continuation of the beds of Newton Bushel and Torquay." * * * "On the contrary, an approach to, if not an identity with, forms of shells discovered generally in the true carboniferous limestone, seems characteristic of the two localities." "Now, whatever doubt may exist as to the true age of the Newton Bushel and Torquay limestones, the position of the Plymouth limestones is clearly amid the slates and sandstones of South Devon, and whatever geological age be assigned to the latter would appear to be common also to the former" (p. 76).

"Those," Mr. De la Beche adds, "who rely very exclusively on the character of organic remains, would probably feel disposed to consider the Torbay and Plymouth beds as equivalent to some such rock as the old red sandstone" (p. 150; see also note, p. 149).

In March 1839, Prof. Sedgwick and Mr. Murchison adopted their present classification of the older sedimentary rocks of Devonshire and Cornwall, partly on the suggestion respecting the age of the South Devon limestones, partly from a re-survey of the country to the south of Dartmoor by Professor Sedgwick, and partly in consequence of an examination of the fossil evidence then determined by Mr. Phillips, Mr. James Sowerby, and the author of this notice. The change in their views they announced in a paper in the Philosophical Magazine and in a memoir read to this Society. In both these documents the most unequivocal testimony is borne to any claim of

mine in having promoted the new classification. (Lond. and Edin. Phil. Mag., April 1839; *antè*, p. 688.)

It is not necessary to offer any remarks on the papers which have been read to the Society, or have been published since those last noticed; and I have forborne alluding to the memoirs on North Devon by Mr. Weaver and the Rev. David Williams. It is requisite, however, to state, that Mr. James Sowerby, from his first inspection of the Bradley fossils to the promulgation of the old red or Devonian classification, considered the limestones to belong to the true carboniferous series.

Such is my brief summary of opinions respecting the age of the limestones south of Dartmoor; and I have confined the extracts solely to them, because I alluded to them alone, when I threw out the suggestion respecting their age. I then knew little of the structure of Devonshire, and great was my surprise when told by Prof. Sedgwick and Mr. Murchison of their bold removal of the whole of the schistose and greywacke rocks of that county and Cornwall, to the old red sandstone—a generalization which could only arise from long, patient, accurate, and extensive practice in the field; and a willingness to adopt a suggestion from whatever quarter it might be advanced.

Three of the foregoing memoirs claim a few remarks; namely, Mr. De la Beche's on Tor and Babacombe Bays; Mr. Prideaux's on Plymouth; and Mr. Phillips's article in the Encyclopædia Metropolitana. It will be most convenient to take Mr. Prideaux's communication first.

That gentleman's inference of the age of the sandstone associated with the limestone was clearly deduced from mineral characters; yet full credit must be given to him for placing part of the limestones in the old red sandstone. He says nothing respecting the zoological evidence, though acquainted with Mr. Hennah's collection of fossils; and he considered the Plymouth limestone might be a different formation from the Torbay.

Mr. De la Beche's memoir on Tor and Babacombe Bays contains a list of twenty-one species of fossils, determined by Mr. James Sowerby. It was of great value as the first attempt to define the zoological characters of the Devonshire calcareous rocks. In the list, two mountain-limestone species, *Cardium aliforme*, (believed by the author of this notice to be a distinct species) and *Bellerophon tenuifasciata*, were positively identified, and two doubtfully, *Spirifera rotundata*, and *Pleurotomaria carinata*; and of the remainder, eight were considered to be new or found only in the Devonshire limestones, and nine too indistinct to be named specifically. The amount of evidence in this list in favour of the Torbay limestones being of the age of the carboniferous series, was very small; yet in the absence of the Trilobites and other fossils of Dudley, at that time considered proofs of the transi-

tion class, it was far more justifiable to adopt the view put forth in Mr. De la Beche's paper, and to assume that the new species were only a legitimate addition to the Fauna of the mountain-limestone, than that they marked a distinct period of organic life. (Geol. Trans., 2nd Series, vol. iii. p. 164.)

Mr. Phillips's lists of fossils in the Encyclopædia Metropolitana were especially valuable, when published, by giving the foreign and British localities at which each species was considered to have been found. The list assigned to the transition series contains thirty-eight species of Devonshire shells, eleven of which are shown to occur also at Paffrath, Bensberg, the Eifel, and in Gothland, then considered true greywacke or transition districts below the old red sandstone. It is worthy of remark, however, that only three species, *Producta depressa*, *Terebratula affinis*, and *Orthoceras circulare*, are stated to be found at Dudley or Ledbury; one, *Pileopsis vetusta*, near Ludlow; and one, *Cirrus acutus*, at Tortworth; and no other English transition localities are mentioned. Twenty-one of the Devonshire shells are further marked as common to the transition and carboniferous systems; and Mr. Phillips, with a just view of the tendency of this evidence, remarks, "We must leave it to future observers to say whether it is quite certain that the limestones of Devonshire really belong to the transition series, a point on which we cannot avoid feeling some doubt." (Encyc. Metrop., p. 573–577.)

At that time Mr. Murchison's Silurian System was not published, and Mr. Phillips had therefore only one of the two terms of comparison necessary for establishing the true age of the limestones. He had also a knowledge of only a part of the fossils of the county. If he had been supplied with these requisites for forming a right judgement, who can doubt the result?

In dwelling for a moment on the attempts to define the age of the limestone, it is curious to perceive how the opinion of the same observer has occasionally oscillated between the mountain-limestone and the upper portions of the transition series; in consequence, no doubt, of the want of that preponderating weight of evidence which is necessary to satisfy the mind of the practical workman, and enable it to rest steadily on its own decisions. If it should be considered that a better result is now attainable, it must be remembered that a great amount of evidence has been lately accumulated, not in Devonshire only, but in other and distant parts of the kingdom. Until the organic remains of the mountain-limestone and of the Silurian system had been determined, it was vain to speculate on the age of a series of fossils, procured from a region but partially examined, beset with faults, and traversed by igneous rocks.

I will now state briefly the zoological evidence on which I assumed that

the Newton Bushel and other limestones would prove to be of the age of the old red sandstone.

It has been already mentioned, that the suggestion was first proposed in December 1837. I had previously examined in part, the corals of the Silurian system and of South Devonshire, and satisfied myself that some of the species are common to both. I had also examined with Mr. James Sowerby, on its first arrival in London, Mr. Hennah's valuable collection of fossils, and had become aware, by the remarks of Mr. Sowerby, that certain of the shells, found near Plymouth, could with difficulty, if at all, be distinguished from mountain-limestone species, and that some were distinct. Immediately after the reading of Mr. Austen's paper in December 1837, I had the pleasure of examining with that gentleman a part of his collection; and though I ventured to dissent from some of the identifications with mountain-limestone shells, pointed out to me (*Pleurorhynchus minax, Terebratula acuminata*), yet the fossils agreed so much in aspect with Testacea of the carboniferous Fauna, that it was impossible to doubt, that the beds from which the specimens had been obtained, had some connexion with the mountain-limestone system. From an examination of the collection, I also ascertained that in the same limestones with these shells, occur corals common in the Silurian system. Through the kind communications of Mr. Austen, I had likewise become aware that the *Calceola sandalina*, a shell previously obtained only from districts on the Rhine, and considered to be transition, existed in Devonshire in beds associated with the limestones; and that he had obtained many new cephalopods and other fossils from the same districts.

It was therefore by combining together this evidence—the presence, in the same series of beds, of shells resembling or identical with mountain-limestone species, of Silurian corals, the *Calceola sandalina*, and various distinct Testacea,—that I was induced to suggest that the South Devon limestones are of an intermediate age between the carboniferous and Silurian systems, and consequently of the age of the old red sandstone. It is necessary to add that Mr. Murchison had shown that there is a regular passage from the old red sandstone upwards into the carboniferous system, and downwards into the Silurian, and that the suites of fossils of the two systems are perfectly distinct.

This amount of evidence would most probably have been insufficient for minds disciplined to draw conclusions only from long-continued and rigidly conducted researches, and have deterred their possessors from hazarding an opinion on a disputed point; but it is hoped, that, for once, a less commendable method of deducing a conclusion has not led to error.

Appended to this notice is a list of fossils, somewhat hastily prepared and

necessarily very incomplete. It has been compiled in part from Mr. Hennah's valuable collection, with the assistance of Mr. James Sowerby; and it is impossible to allude to that collection without speaking in terms of the warmest admiration of the liberality of spirit, which placed the whole series at the command of Prof. Sedgwick and Mr. Murchison; and of the zeal and assiduity with which the smallest specimens have been collected and preserved. I have also been permitted to use a valuable manuscript list drawn up by Mr. Austen, in part from specimens named by M. de Verneuil; and I have taken advantage of the information contained in the published lists of Mr. De la Beche and Mr. Phillips. I may be permitted to add, that I have compared, as far as I have been able, the species mentioned in those documents with accessible specimens, particularly a portion of Mr. Austen's valuable collection, and another kindly lent me by Mr. Daniel Sharpe.

The list contains 62 species, 10 of which have been assigned to carboniferous fossils, and 13 to Silurian; and the remaining 39 have not, it is believed, been found in England except in the limestones and associated beds of South Devonshire. In the list is not noticed a large number of fossils still unnamed, including many species in Mr. Hennah's and Mr. Austen's collections.

The ten species considered to agree with mountain-limestone fossils, do not include one decided coral common to the carboniferous and Devonshire limestones. The shells are *Terebratula flexistria**, *T. acuminata*, *T. pugnus*, *T. Mantiæ**, *Spirifera* (*Trigonotreta*) *oblata**, *S. subconica?* *Pecten plicatus*, *Pileopsis vetustus*? *Buccinum imbricatum* and *B. acutum**. The four species marked with an asterisk I have not seen, but they are included on the authority of Mr. Austen's and Mr. Phillips's lists. The *Cyrtia* and *Pileopsis* are also not positively identified.

The whole of the nine species occur in that lower portion of the carboniferous limestone series, to which the term carboniferous or mountain-limestone has been particularly applied; but it is a subject of regret, that we have not more precise data respecting the distribution of organic remains in that formation, which not unfrequently equals in thickness the oolitic series of Wiltshire; yet it is well known that the fossils of the upper calcareous divisions of that oolitic series differ considerably from those in the lower.

On the fossils considered peculiar to the Devonshire limestone it is not necessary to offer any remarks, for the present comparison is confined solely to England.

Of the thirteen Silurian fossils eight are corals and five are shells. The latter are *Terebratula prisca*, *T. aspera*, *T. Wilsoni*, *Spirifera* (*Trigonotreta*)

cassidea, and *Spirifera trapezoidalis*, but the *T. Wilsoni* and *S. trapezoidalis* are probably distinct from the Silurian shells. The corals are *Favosites polymorpha*, *F. spongites*, *F. Gothlandica*, *F. fibrosa*, *Porites pyriformis*, *Cyathophyllum turbinatum*, *C. cæspitosum* and *Fenestella antiqua*. The *Favosites polymorpha* occurs abundantly in Devonshire, and it is not rare in the upper Silurian formations; but the specimens which I have seen from Plymouth and Newton Bushel resemble more nearly the variety figured by Goldfuss from Paffrath than that found in the Ludlow rocks; the *Porites pyriformis* is equally abundant in the limestones of Devonshire and Wenlock; but the remaining five species, as far as I am acquainted with the collections of Mr. Hennah, Mr. Austen, and Mr. Sharpe, are not common. The more abundant corals are those peculiar to the limestones.

A vast amount of work remains to be done with respect to the Devonshire organic remains; but I rejoice to know that the task has been placed in the hands of Mr. Phillips, who is not only well qualified but ready to overcome every difficulty; and it cannot be long before we are supplied with the fullest and most satisfactory information.

If it should be urged, that it was unjustifiable to assume from organic remains alone, the age of the Devonshire limestones, it may be replied that at that time no base line had been laid down, south of Dartmoor, from which an order of superposition could be established. It may be also stated, that organic remains had not long before proved faithful guides in a district in which mineral character and order of superposition were inapplicable. Through the exertions of Captain Smee, Colonel Pottinger, Colonel Sykes, and Captain Grant, we had become aware of the existence of two series of formations in Cutch and the Desert to the eastward; and that one of them could be placed in the parallel of the oolite series of England, because its fossils were generically and in part specifically the same, and differed as a whole generically and essentially from the fossils of any known transition or tertiary district. In this instance we have an example of organic remains enabling the geologist to unite tracts separated by continents,—not, be it observed, by establishing the identity of the fossils of subdivisions of formations, but on the broad basis of the Fauna of a peculiar period in the history of our globe. (See *antè*, pp. 289, 715.)

Again, another instance may be quoted of the value of organic remains, if rightly applied, in determining the relative geological age of a distant region, and in the present case of one inaccessible to Europeans. The Ammonites lately laid upon the Society's table by a near relative of the lamented Captain Alexander Gerard, and specimens of which have been long known, prove

the existence on the Tartar side of the Himalaya mountains of a secondary formation, not by specific identifications, but by the structure of the chambers of the shells being of that peculiar nature, which is found only in Ammonites of the secondary series. It is not necessary to quote examples of districts, nearer home, which have been identified by organic remains. I beg, however, it may be clearly understood, that in advocating the value of fossils, I would not expunge from the geologist's consideration the aid to be derived from order of superposition, and, under a right control, from the use of mineral composition and lithological structure. I would also advise him not to depend upon his own limited sources of knowledge, but to seek the aid of the philosophical zoologist, who can teach him to reason justly on the distribution of animal life—the accidents to which it is liable—the changes which such accidents may produce, or the means provided by nature to resist them —and on the effects which a permanent alteration in the inhabiting medium may work on the form and size of a shell or coral.

I will now point out two cases, in which errors have apparently been committed by attempting to establish a parallelism of formations by mineral characters, and an insufficient inquiry into the organic remains.

At the commencement of the present year my attention was more particularly redirected to M. Dumont's work on part of Belgium, published in 1832*, and especially to his identification of the formations contained in that district with those of the Silurian System. M. Dumont divides the *terrain anthraxifère* of M. d'Omalius d'Halloy, which occurs immediately beneath the true coal-measures, into the following four systems :

1. *Système calcareux supérieur.*
2. *Système quartzo-schisteux supérieur.*
3. *Système calcareux inférieur.*
4. *Système quartzo-schisteux inférieur.*

Beneath the last occurs the *terrain ardoisier.*

It was apparently no part of M. Dumont's object at that time to place the Belgian systems on a parallel with the then established formations of England, though the list of fossils from the *Système calcareux supérieur* identifies it completely with the mountain-limestone. M. Dumont, it is true, considers his lowest *système* to be the representative of the old red sandstone ; but the identification was made on mineral characters, and at the suggestion of Mr. Murchison.

The *Système quartzo-schisteux supérieur* was placed by Dr. Buckland in

* Mémoire sur la Constitution Géologique de la Province de Liège, 1832.

1821 on a parallel with the old red sandstone, having taken for his base line the limestone of Namur, the true representative of the mountain-limestone. (Annals of Phil. 1821, June, p 465.)

Mr. Conybeare, in "The Outlines of England and Wales" (note, p. 468, 1822), gives the following list of the formations beneath the coal strata of Belgium and the North of France, with English equivalents, the former being extracted from M. d'Omalius d'Halloy's Mémoire sur la Géologie du Nord de la France, (Journal des Mines, tome 24, 1806.)

Belgium, &c.	England.
Coal strata	The same.
Shale and grit	Millstone grit and shale.
Limestone alternating with slate-clay	Carboniferous limestone.
Red and variegated grits alternating with slate-clay	Old red sandstone.
Yellow granular quartz	
Grit and breccia	
Clay-slate	Transition slate.

Thus placing all the beds between "the limestone alternating with slate-clay" and "the clay-slate" in the old red sandstone.

This arrangement M. Rozet appears to have followed in his description of Belgium, as he refers the psammites, &c., between the black limestone and the schists, to the old red sandstone; alluding at the same time to the account of that formation, in The Outlines of Mr. Phillips and the Rev. J. Conybeare. (Ann. des Sciences Nat., tome 20, p. 146, 1830.)

It was, I believe, at the *Réunion extraordinaire* of the Geological Society of France, at Mezires, in September 1835, (*Bulletin Soc. Géol. de France*, tome vi. p. 345, 1835,) that the first attempt was made to compare the Belgian formations with the Silurian system of England. At that meeting, Dr. Buckland drew up a table in which the following equivalents are given:

Système calcareux supérieur.....Mountain-limestone.
(Old red sandstone wanting.)
Système quartzo-schisteux supérieur.....The Ludlow rocks.
Système calcareux inférieur.....The Dudley and Plymouth rocks.
Système quartzo-schisteux inférieur.....The Caradoc sandstone.
Builth and Llandeilo flags wanting.

With respect to the above comparisons it should be remembered, that in 1835 the Silurian system had not been made known in its full details, the fossils having been determined only in part; and the resemblance of the Belgian corals to Dudley species, justified a comparison of the calcareous strata of M. Dumont's systems with the Dudley and Wenlock limestones.

During the discussions which took place on the identity of the English and Belgian formations, M. Constant Prevost stated, that the *calcaire bleu* of the

système calcareux inférieur reminded him strongly of the limestones of Plymouth, and that the marble of Heer, near Mezieres, composed for a great part of indistinct corals, and subordinate to the *quartzo-schisteux supérieur*, appeared to him analogous to the limestones of Babbacombe. (Bulletin, pp. 353, 349.) Mr. Greenough expressed doubts of the identity of the Plymouth and Dudley limestones; and stated that he had remarked the constant absence in the *système calcareux inférieur* of the Trilobites, and particularly the *Calymene Blumenbachii*, so common at Dudley. (Bulletin, p. 353.) The above remarks are valuable, bearing upon the question under examination, and they teach us the value of not rejecting from our consideration negative evidence, when attempts are made to compare systems of formations.

At an ordinary meeting of the Geological Society of France, in December 1837, M. Rozet repeated his opinion that the old red sandstone is not wanting in Belgium, being well developed between Dinant and Namur; and M. Constant Prévost observed, that during the *Réunion* of the French Society at Mezieres, he had observed a great mass of psammites, red grits, and quartzose conglomerates in the district mentioned by M. Rozet, actually interposed between the Silurian schists and the carboniferous limestones, and representing consequently the old red sandstone of the English*. (Bulletin Soc. Géol. de France, tome ix. p. 84.)

In 1838, M. Dumont visited England for the purpose of examining the Silurian region, and on his return to Belgium he laid before the Royal Academy of Brussels a comparative table† of the Belgian and Silurian formations. This document differs from Dr. Buckland's table only in drawing more closely the terms of comparison—in identifying the two upper divisions of the *terrain ardoisier* with the Cambrian system—and in omitting all reference to the Plymouth limestone. The old red sandstone of England is considered to have no equivalent in Belgium. In the Report which accompanies this table, M. Dumont remarks on the perfect accordance in the structure of the two regions, but he says that in Belgium the *calcaire inférieur* is most strongly developed, and in Siluria the schists and psammites. He doubts if there be any representative of the old red sandstone in Belgium. If it be wanting, he says, its place is marked between the *système quartzo-schisteux supérieur* and the *système calcareux supérieur*; but if it exists, it ought to be regarded as an extraordinary development of the superior psammite of the *quartzo-schisteux supérieur* or upper Ludlow rock. The fossils considered as characteristic of

* Dr. Buckland has kindly permitted me to refer to some manuscript sections made during the Mezieres Meeting; and in those between Namur and Dinant, as well as those near Huy and at Engis, the old red sandstone is exhibited underlying the mountain-limestone.

† Bulletin Acad. Roy. de Bruxelles, 1838, No. x. p. 634, *et seq.*

the divisions of the Silurian system in England, he is of opinion are good for this country, but that differences more or less marked ought to occur in other countries, and that such actually exist in Belgium.

In M. Dumont's work, justly valued for unravelling the structure of an intricate country, for its minute mineralogical and local details, and for its excellent map, lists of fossils are appended to each system. On an inspection of them, it was impossible not to be struck with the great proportionate number of mountain-limestone or Devonshire fossils, and the few solely Silurian. In briefly remarking on their contents, I will take the lists in a descending order, for the sake of departing from the *système calcareux supérieur*, which is clearly proved to belong to the carboniferous series by containing 38 well-known English mountain-limestone species.

Of the ten shells specifically determined, from the *système quartzo-schisteux supérieur*, namely, *Spirifera attenuata*, *S. bisulcata*, *S. lineata*, *S. pinguis*, *Producta aculeata*, *Strophomena pileopsis*, *Pecten plicatus*, *Terebratula aspera*, *T. Wilsoni*, and *T. lineata*,

Five—*Spirifera bisulcata*, *S. pinguis*, *Producta aculeata*, *Strophomena pileopsis*, and *Terebratula lineata*, are also mountain-limestone species;

One—*Pecten plicatus*, is believed to occur both in the mountain-limestone and Devonian strata;

One—*Spirifera attenuata**, is peculiar to the Devonian series;

One—*Terebratula aspera*, is common to the Devonian and Silurian beds;

Two—*Spirifera lineata* and *Terebratula Wilsoni*, are true Silurian fossils, if the identification be right; but the characters of the latter frequently lead to erroneous determinations.

In the *système calcareux inférieur* five species of shells are specifically mentioned with references, and ten of corals.

The shells are, *Spirifera attenuata*, *Terebratula prisca*, *T. aspera*, *T. explanata*, and *Spirifera lineata*. The first is probably the shell peculiar to the Devonian series, but if it be correctly identified it is a mountain limestone species. *Terebratula prisca* and *T. aspera* are found, as already stated, both in the Silurian and Devonian series; *Terebratula explanata* is generally considered a variety of *T. prisca*, and *Spirifera lineata* is given with a doubt.

The ten species of corals are, *Fenestella* (*Retepora*) *antiqua*, *Anthophyllum bicostatum*, *Cyathophyllum dianthus*, *C. quadrigeminum*, (including *Manon favosum*, see Goldfuss, *corrigenda*, vol. i.,) *C. cæspitosum*, *Strombodes* (*C.*) *plicatus*, *Astrea* (*C.*) *ananas*, *A.* (*C.*) *pentagona*, *Favosites* (*Calamopora*) *spongites*, and *F.* (*C.*) *polymorpha*.

* The shell called *Spirifera attenuata* on the Continent is one of the most characteristic fossils of the beds under consideration, being noticed in every published list; but it differs essentially from the mountain-limestone fossil called *Spirifera attenuata*, in the ribs being simple and regular in size, and in the greater projection of the raised central part of the upper valve.

Two of the species—*Astrea pentagona* and *Cyathophyllum quadrigeminum*, have been noticed in England only in the Devonian series.

Four—*Fenestella antiqua*, *Favosites polymorpha*, *F. spongites*, and *Cyathophyllum cæspitosum*, are common to the Devonian and Silurian systems.

Three—*Strombodes plicatus*, *Cyathophyllum dianthus*, *Astrea ananas*, have hitherto been obtained in England only in the Silurian formations; but it is possible that the *S. plicatus* may be the *Astrea* (*Cyathophyllum*) *helianthoides*, a Devonian and not a Silurian coral.

The *Anthophyllum bicostatum* has not been noticed in England.

A summary of these details gives twenty-five fossils, only five of which can be said to be peculiar to the Silurian system, viz. *Astrea* (*Cyathophyllum*) *ananas*, *Strombodes plicatus*, *Cyathophyllum dianthus*, *Terebratula Wilsoni*, and *Spirifera lineata*? but the *Terebratula* is probably not an accurate identification; and the *Spirifera* is given by M. Dumont with a doubt*.

The lists which I have ventured to analyse are small, but the evidence they afford is valuable, consisting not in the absence of characteristic suites of peculiarly Silurian fossils, but in the presence of Devonian and carboniferous species, which have not been detected in any of the Silurian beds. If it should be objected that an attempt has been made to establish a case by lists and not by specimens, it may be replied that the lists bear all the internal evidence of having been carefully prepared. They contain no species which may be considered as apocryphal, and they possess a unity of character with lists from other localities in the same country, drawn up by independent observers. It should also be remembered that M. Dumont's judgement while preparing the lists could not have been biased by any theory; for he had none to advocate. His sole object in examining the country around Liege was to work out a difficult district, and to prove the order of superposition of strata strangely contorted and inverted. This task it must be universally allowed, he accomplished in a manner deserving of all praise. At that time, he thought not of identifying his systems with those of England; and if it should be proved that the comparison is erroneous, the failure must be solely ascribed to not taking into his consideration the only means by which distant countries can be identified, a right application of organic remains. There can be no doubt also, that M. Dumont was guided, to a great extent, in his classification of 1838, by having determined in 1836, that the *système calcareux inférieur* was the equivalent of the Eifel limestone. (See Bull. Soc. Géol. de France, t. viii. p. 77. Dec. 1836.)

I am called upon to offer a few remarks on one other case.

During the *Réunion extraordinaire* of the Geological Society of France, at Porrentruy, in September 1838, M. de Verneuil read a notice on the an-

* The fossils from the *Système quartzo-schisteux inférieur* having been identified on insufficient evidence, any notice of them has been considered unnecessary.

cient formations of the Bas Boulonnais, which he had visited during the preceding summer, in company with MM. d'Omalius d'Halloy and Dumont, previously to a joint excursion to England. The principal object of the paper was to establish the existence of two limestones, one the equivalent of the mountain-limestone of England, and the other of the Wenlock, M. de Verneuil having been led to suppose that there existed in the Bas Boulonnais a true Silurian district, in consequence of the examination of a collection of fossils sent to him, the preceding autumn, by M. d'Archiac. This limestone M. de Verneuil also placed on a parallel with the *système calcareux inférieur*, of M. Dumont and of the limestone of the Eifel. (Bulletin Soc. Géol. de France, tome ix. pp. 388, 389; 1838.)

M. Dumont, in the Report made to the Bruxelles Academy in 1838, likewise states, that his four *systèmes anthraxifères* of Belgium are found in the Boulonnais. (Bulletin Acad. Roy. de Bruxelles, 1838, No. x. p. 638.)

M. Rozet had previously (1828) pointed out the existence of two limestones, the upper of which he placed on the parallel of the mountain-limestone, and the lower or black beneath the old red sandstone, which he stated was wanting in the Boulonnais; but in his memoir on the Ardennes and Belgium he considers them as two divisions (*étages*) of the same formation, and assigns them a position above the old red sandstone. (Description Géologique du Bas Boulonnais, pp. 99, 117, 1828; Annales des Sciences Naturelles, tome xix. p. 145, 1830.)

It is not necessary to offer any remarks on the proofs of the existence of the mountain-limestone, for it has been long known to occur in the Bas Boulonnais.

The evidence in support of the presence of an equivalent of the Wenlock limestone rests partly on infraposition, and partly on certain fossils, stated to be common to the Boulonnais, Dudley, Wenlock, the Eifel, and Belgium. (Bull. Soc. Géol. de France, tome. ix. p. 392.)

At the *Réunion extraordinaire* of the French Society at Boulogne in September last (1839), and at which some of the Fellows of this Society assisted, M. de Verneuil's views with respect to that limestone were fully admitted. When, however, doubts arose at the commencement of this year relative to the age of the Belgian *systèmes*, Mr. Murchison suggested to me, that the Boulonnais beds would prove to be of the equivalents of the Devonian. It is necessary to state, that Mr. Murchison attended the meeting of the French Society. To determine the question, if possible, by the aid of organic remains, that gentleman procured, by the kind assistance of M. Dutertre-Yvart, a collection of specimens in the Boulogne Museum. I have had the pleasure of examining it, and comparing its contents with the list drawn up by M. de Archiac and M. de Verneuil, and published in the French Bulletin.

The following are the results obtained from both sources of information;

and I beg to add, that the list just mentioned was evidently prepared with the utmost care and scrupulous attention to the characters of the fossils, and without the least appearance of bias to preconceived opinions. The amount of species is twenty:—*Fenestella antiqua* (*Retepora prisca*, De Verneuil); *Aulopora tubæformis* (*A. conglomerata*, De Vern.); *Favosites polymorpha*, *F. spongites* (*Calamopora spongites*, De Vern.); *Cyathophyllum turbinatum* (including *C. radicans*), *C. cæspitosum*; *Strombodes vermicularis* (*Cyathophyllum vermiculare*, De Vern.); *Astrea ananas* (*C. ananas*, De Vern.); *Serpula omphaloides*, *Orthis transversalis*? *O. umbraculum* (*Spirifera crinistria*, Phillips); *Spirifera attenuata*, *Terebratula prisca*, *T. aspera*, *T. concentrica*, *T. plicatella*, *Producta aculeata*, *Terebra Hennahii*, *Euomphalus radiatus*, and *Orthis similis**.

The distribution of the twenty species contained in the above list, is as follows:—

One,—*Orthis umbraculum*, is also a mountain-limestone shell.

Five,—*Strombodes vermicularis*, *Terebratula concentrica*, *Spirifera attenuata* (not the mountain-limestone shell), *Terebra Hennahii*, and *Euomphalus radiatus*, are true Devonian fossils.

Seven,—*Fenestella antiqua*, *Favosites polymorpha*, *F. spongites*, *Cyathophyllum turbinatum*, *C. cæspitosum*, *Terebratula prisca*, and *T. aspera*, occur both in the Devonian and Silurian systems.

Two,—*Aulopora tubæformis* and *Astrea ananas*, have not yet been seen by me in the Devonshire collections.

The *Orthis transversalis* is distinct from the *Leptæna transversalis* of the Silurian system, and the *Terebratula plicatella* is believed to be distinct from the *Terebratula borealis* of the same system.

The *Producta aculeata* (*P. subacuta*, De Verneuil), *Serpula omphaloides*, and *Orthis similis*, have not yet been noticed by me in England.

The inference which I think may be drawn from the above enumeration is, that there exists in the Boulonnais a series of beds characterized by a suite of fossils intermediate between that of the Silurian system and that of the mountain-limestone, or on a parallel with the old red sandstone.

The preceding remarks partake too much, I fear, of the tone of personal advocacy; but it was my duty to show what share I have had in the development of the Devonian or old red system. How small my share is, I need not say—how large that of Professor Sedgwick and Mr. Murchison, will soon be known to all.

* The three last species are added from a collection of Boulonnais fossils in the cabinet of M. Bouchart, and which I have been permitted to examine since the reading of the paper (May, 1840). A fuller list of the Boulonnais shells will appear in Mr. Murchison's paper, "Sur les Roches Devoniennes qui se trouvent dans le Boulonnais et les pays limitrophes," and which will be published in the forthcoming number of the Bulletin of the Geological Society of France.

LIST OF FOSSILS FROM SOUTHERN DEVONSHIRE, REFERRE DTO IN THE PRECEDING NOTICE, p. 728.

The species marked (1) are given on the authority of Mr. Austen's list; those marked (2) on the authority of Mr. James Sowerby; (3) on that of Mr. J. Phillips; for those without a figure the compiler of the Table is responsible. For the localities, the Rev. R. Hennah and Mr. Austen are the principal authorities. The numerals refer to the plates which illustrate the volume.

Genera and Species.	References.	Systems in which the Species are found in England.	Localities in Devonshire.
Scyphia turbinata	Goldf. 2, f. 13, LVIII. 9.	Devonian.	Plymouth.
Coscinopora placenta?	Goldf. 9, f. 18, LVIII. 5-d.	Devonian.	Ibid., Ogwell, Newton Bushel.
Petraia (Munster) Celtica	Turbinolia Lam^{x}. Exp. M. 78, f. 7, 8, LVIII. 6.	Devonian.	Dinas Cove, Padstow, Berry Po-
Strombodes vermicularis	Cyathophyl. Goldf. 17, f. 4, LVIII. 7-a.	Devonian.	Plymouth, Ogwell. [meroy, &c.
Cystiphyllum Damnoniense	LVIII. 11-b.	Devonian.	Ibid. Ibid.
Cyathophyllum turbinatum	Goldf. 16, f. 8. Silur. Syst. 16, f. 11-a.	Devonian.—Silurian.	Ibid.
—— cæspitosum	Goldf. 19, f. 2. Silur. Syst. 16, f. 10, LVIII. 8-d.	Devonian.—Silurian.	Ibid. Ibid., Torquay.
Astræa pentagona	De Blainv. Man. d'Actinol. 375. Cyathophyl. Goldf. 19, f. 3. LVIII. 1-a.	Devonian.	Ibid. Ibid. Ibid.
—— helianthoides	De Blainv. Man. d'Actinol. 375. Cyathophyl. not A. helianthoides. Goldf. 20, f. 2.	Devonian.	Ibid.
—— Hennahii	LVIII. 3-b.	Devonian.	Ibid., Barton.
Porites pyriformis	Ehrenberg, Silur. Syst. 16, f. 2-e. LVIII. 4-f.	Devonian.—Silurian.	Ibid., Ogwell.
Favosites polymorpha	Goldf. 27, f. 4, Silur. Syst. 15. f. 2.	Devonian.—Silurian.	Ibid., Ibid., Barton, &c.
—— spongites (note *b*.)	Goldf. 28. f. 1 f. Silur. Syst. 15 bis, 8-a.	Devonian.—Silurian.	Ibid., Ibid.
—— Gothlandica	Lamark, Goldf. 26, f. 3. Silur. Syst. 15 bis, f. 3–4.	Devonian.—Silurian.	Plymouth, Ibid.
—— fibrosa	Goldf. Silur. Syst. 15 bis, f. 6.	Devonian.—Silurian.	Fowey, Barton.
—— ? ramosa (note *c*.)	Brassart, Mus. Geol. Soc. London.	Devonian.	Near Chudleigh.
Stromatopora polymorpha	Goldf. 64, f. 8, LVIII. 2.	Devonian.	Appleway.
Fenestella antiqua	Gorgonia, Goldf. 36, f. 3. Silur. Syst. 15, f. 16, LVIII. 10-b.	Devonian.—Silurian.	Plymouth, Fowey, &c.
Pleurodictyum problematicum[1]	Goldf. 38, f. 18.	Devonian.	West Ogwell.
Terebratula flexistria[1]	Phillips, Geol. Yorks. Part 2, Pl. 12, f. 33,34.	Devonian.—Carbonifer.	Newton Bushel.
—— acuminata[1]	Sow. M.C. 324, f. 1; 495, f. 1-3. Phill. Geol. Yorks. 12, f. 4-9.	Devonian.—Carbonifer.	Ibid.
—— pugnus[1]	Sow. M.C. 497, f. 1, 6. Phill. Geol. Yorks. 12, f. 17,	Devonian.—Carbonifer.	Plymouth, Newton Bushel.
—— Mantiæ[1]	Sow. M.C. 277, f. 1.	Devonian.—Carbonifer.	Ibid. Ibid.
—— primipilaris	Schlotheim, Von Buch, Terebrat. p. 68, pl. 2, f. 29, LVII. 5, 6.	Devonian.	Ibid. Ibid. [quay.
—— concentrica[1]	Von Buch, Terebrat. p. 103.	Devonian.	Newton Bushel, Ogwell, Tor-
—— borealis[3]	Schlotheim, 20, f. 6.	Devonian.	Ibid. Ibid. Ply-
—— ferita	Von Buch, Terebrat. p. 76, pl. 2, f. 37.	Devonian.	Plymouth. [mouth.
—— prisca[1]	Schloth. 17, f. 2. Atrypa affinis, Sow. M.C. 324, f. 2. Silur. Syst. 6, f. 5.	Devonian.—Silurian.	Ibid. Newton, Torquay.
—— aspera[1]	Schloth. 18, f. 3. Atrypa, Silur. Syst. 12, f. 5.	Devonian.—Silurian.	Ibid. Ibid. Ibid.
—— Wilsoni?	Sow. M.C. 118, f. 3. Silur. Syst. 6, f. 7.	Devonian.—Silurian?	Ibid. Ibid.
Spirifera oblata[1]?	Sow. M.C. 168, Trigonotreta, Bronn, Leth. Geog. 2, f. 16-b.	Devonian.—Carbonif.?	Torquay. Ibid.
—— distans[2]	Sow. M.C. 494. Ency. Metrop. Art. Geol. 576.	Devonian.—Carbonifer.	Ibid. Ibid.
—— speciosa[1]	Trigonotreta, Bronn, Leth. Geognos. 2, f. 15-d.	Devonian.	Ogwell, Berry.
—— ostiolata[1] (note *d*.)	Trigonotreta, Bronn, Leth. Geognos. 2, f. 14-c.	Devonian.	Newton Bushel, Torquay.
—— aperturata[1] (note *e*.)	Trigonotreta, Bronn, Leth. Geognos. 2, f. 13-b.	Devonian.	Ibid.
—— cassidea[1]	Trigonotreta, Bronn, Leth. Geognos. 2, f. 9-c.	Devonian.—Silurian.	Ibid. Ogwell.
—— subconica?	Martin, Petrif. Derb. 47, f. 6, 7, 8.	Devonian.—Carbonifer.	Ibid.
—— trapezoidalis[1]	Dalman, see Silur. Syst. 5, f. 14.	Devonian.—Silurian?	Ibid.

GENERA AND SPECIES.	REFERENCES.	Systems in which the Species are found in England.	Localities in Devonshire.
Strygocephalus Burtini[1].	De France, Dic. Sciences Nat. pl. 75. Terebrat. porrecta, M.C. 576, f. 1.	Devonian.	Newton Bushel, E. & W. Ogwell, Bradley.
Producta rugosa[1]	Strophomena, Bronn, Leth. Geognos. 2, f. 8-c.	Devonian.	Ibid. Plymouth.
Calceola sandalina[1]	Lamarck, Anim. sans Verteb. 2 edit. tome 7, p. 294.	Devonian.	Chercombe Bridge, E. Ogwell.
Pleurorhynchus, sp. new ?		Devonian.	Plymouth. Bradley.
Megalodon cucullatus[2]	Sow. M.C. 568.	Devonian.	Newton Bushel, E. Ogwell.
——— carinatus	Goldf. 132, f. 9.	Devonian.	Ibid. Ibid.
Pterinea radiata[3]	Goldf. 119, f. 7.	Devonian.	Ibid.
Pecten plicatus[2]	Sow. M.C. 574, f. 3.	Devonian.—Carbonifer.	Plymouth.
Corbula Hennahii	Sow. LVI. 1.	Devonian.	Ibid.
Pileopsis vetusta	Sow. M.C. 607, f. 1-3.	Devonian.—Carbonifer.	Newton Bushel. [Bridge.
Trochus Boueii	Steininger, Mem. Geol. Soc. France, t. i. Pl. 23, f. 4.	Devonian.	W. Ogwell. (Slate.) Chercombe
Euomphalus radiatus	Goldfuss, MS.	Devonian.	Newton Bushel.
Turritella abbreviata	Sow. M.C. 565, f. 2.	Devonian.	Ibid. Chudleigh.
——— bilineata ?	Goldfuss, MS.	Devonian.	Ibid.
Murex Harpula	Sow. M.C. 578, f. 5.	Devonian.	Bradley near Newton Bushel.
Terebra Hennahii	Sow. Ency. Metro. Art. Geol. p. 578, Query, Mém. Geol. Soc. France, t. 2, Pl. II. f. 25.	Devonian.	Plymouth.
Buccinum spinosum[2]	Sow. M.C. 566, f. 4.	Devonian.	Bradley near Newton Bushel.
——— breve[2]	Sow. M.C. 566, f. 3.	Devonian.	Ibid.
——— acutum[2]	Sow. M.C. 566, f. 1. Phill. Geol. York. Pt. II., Pl. 16, f. 11, 23.	Devonian.—Carbonifer.	Ibid.
——— imbricatum[2]	Sow. M.C. 566, f. 2. Phill. Geol. York. Pt. II., Pl. 16., f. 9, 17, 20.	Devonian.—Carbonifer.	Ibid.
Bellerophon striatus	Bronn. Leth. Geog. 1, f. 11-c.	Devonian.	Newton Bushel.
Orthoceras tubicinella[2]	Sow. LVII. 29.	Devonian.	Ibid. Plymouth.
Cyrtoceras nodosa[1]	Spirula, Bronn, Leth. Geog. 1, f. 4-b.	Devonian.	Ibid.
Brontes flabellifer	Goldfuss, Act. Acad. Cæs. Leop. Nat. Cur., Tom. XIX. Pl. 33, f. 3.	Devonian.	Ibid.

* No reference is made in this table to foreign localities, as the comparison of the Devonian fossils with those of Westphalia, the Eifel, and other Continental regions, will be fully given in the papers about to be laid before the Society by Professor Sedgwick and Mr. Murchison.

(*b.*) *Favosites spongites*. It is extremely difficult to separate some of the Devonian specimens, assigned provisionally to this species, from a coral which occurs in the mountain-limestone at Bristol. In polished sections no traces can be detected of connecting foramina, and the character of the tubes is also the same in the carboniferous and Devonian fossils. These corals bear much more the aspect of Fischer's genus *Chaetetes* than that of *Favosites*. For an opportunity of examining several specimens of the Bristol coral I am indebted to Mr. Pratt.

(*c.*) *Favosites? ramosa*. In the collection of specimens from the Eifel, presented to the Geological Society by Mr. Willimott, is one labelled *Favosites ramosa* (nob.). It was obtained originally from M. Brassart, of Bonn. The specimen is evidently not a *Favosites*; but its state of decomposition, and that of several others kindly lent me by Mr. Murchison, forbid the characters being properly ascertained. The fossil consists of long slender branches, perforated down the centre, and presents a carious structure resembling that of the genus *Scyphia*.

(*d.*) The *Spirifera rotundata* of the mountain-limestone is believed by some conchologists to be the same species as the *Spirifera ostiolata*, but a comparison of specimens proves that the shells are distinct. *S. rotundata* has broad flat ribs, which subdivide at irregular distances from the beak, and are traversed transversely only by fine lines of growth: in *S. ostiolata* the ribs are proportionably less broad, do not subdivide; and in addition to fine lines of growth, are traversed longitudinally by numerous delicate striæ: minute prominences are also visible under the lens, irregularly scattered, and having no dependence on the intersection of the lines of growth with the longitudinal striæ.

(*e.*) Bronn considers *Spirifera bisulcata* of the carboniferous limestone the same species as *Spirifera aperturata*; but the beaks of *S. bisulcata* are in contact, while those of *S. aperturata* are separated. The elevated central portion in the larger valve of *S. aperturata* is also distinguished by the ribs being slightly in relief, and by the two ribs bounding the elevated portion forming sharp ridges. It has been thought necessary to enter into these details to assist in defining the limits of the range downwards in the series of mountain-limestone species.

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18.	Nouvelles Annales du Muséum d'Histoire Naturelle, ou Recueil de Mémoires publiés par les Professeurs de cet Etablissement et par d'autres Naturalistes, sur l'Hi-	

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	stoire Naturelle, l'Anatomie et la Chimie, tome 4, 2 et 3 livraisons. 4to. Paris 1835.	The Museum of Natural History, Paris.
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	Reply to Mr. Woodward's Remarks on the Coralline Crag, with Observations on certain Errors which may affect the Determination of the Age of Tertiary Deposits, by Edward Charlesworth, Esq., F.G.S. 8vo. London 1835.	The Author.
	Mémoires de la Société Géologique de France, tome premier, deuxième partie. 4to. Paris 1834.	The Geological Society of France.
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	Table des Matières et des Auteurs pour le quatrième volume du Bulletin de la Société Géologique de France, par M. Clement Mullet. 8vo. 1834.	.....
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Dec. 1.	Arboretum et Fruticetum Britannicum, or Trees and Shrubs of Britain, Native and Foreign, Hardy and Half-Hardy, Pictorially and Botanically delineated, and Scientifically and Popularly described; by J. C. Loudon, Esq., F.G.S.; for the year 1836. 8vo. London 1836.	The Author.
	The Magazine of Natural History, and Journal of Zoology, Botany, Mineralogy, Geology, and Meteorology; conducted by J. C. Loudon, Esq., F.G.S., &c.; for the year 1836. 8vo. London 1836.	The Conductor.
	The London and Edinburgh Philosophical Magazine, and Journal of Science: Third Series; by Sir David Brewster, K.H., LL.D., F.R.S. L. and E.; Richard Taylor, F.S.A., L.S., G.S., Astr. Soc., &c.; and Richard Phillips, F.R.S. L. and E., F.G.S., &c.; for the year 1836. 8vo. London 1836.	Richard Taylor, Esq., F.G.S.
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	Bulletin de la Société Impériale des Naturalistes de Moscou, tome 9. 8vo. Moscou 1836.	.....
	Report of the Expedition for exploring Central Africa from the Cape of Good Hope, June 23rd, 1834, under the superintendence of Dr. A. Smith. 8vo. London 1834.	The Society for Exploring Central Africa.
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	and Auxiliary Royal Asiatic Society; edited by the Secretary. No. 13, October 1836. 8vo. Madras.	Madras Literary Society.
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	Considerazioni Geologiche sullo Zolfo, del Socio Professore C. Gemmellaro. 4to. 1833.	The Author.
	Bulletin de la Société Géologique de France, tome 8, feuilles 5–9. 8vo. 1837.	The Geological Society of France.
	Geognostische und physikalische Beobachtungen über die Vulkane des Hochlandes von Quito, von Alexander von Humboldt. 8vo. Berlin 1837. From the Annalen der Physik und Chemie, Band xxxx. no. 2.	The Author.
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	Table showing the mean temperature, as also the mean height of the Barometer in each month in the $3\frac{1}{2}$ years ending 30th June 1837, with the extremes of each and	

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	the days on which such extremes occurred, by Joseph Templeman, of the Colonial Secretary's Office, Newfoundland.	The Author.
Dec. 13.	Arboretum et Fruticetum Britannicum, or Trees and Shrubs of Britain, Native and Foreign, Hardy and Half Hardy, pictorially and botanically delineated, and scientifically and popularly described, by J. C. Loudon, for the year 1837. 8vo. London 1837.	The Author.
	Loudon's Magazine of Natural History, conducted by Edward Charlesworth, Esq., F.G.S.,—New Series for the year 1837. 8vo. London 1837.	The Conductor.
	The London and Edinburgh Philosophical Magazine and Journal of Science, Third Series, by Sir David Brewster, K.H., LL.D., F.R.S., L. and E., &c.; Richard Taylor, Esq., F.S.A., L.S., G.S., Astr. Soc., &c.; and Richard Phillips, F.R.S., L. & E., F.G.S.; for the year 1837. 8vo. London 1837.	R. Taylor, Esq., F.G.S.
	The Repertory of Patent Inventions, and other Discoveries and Improvements in Arts, Manufactures, and Agriculture, for the year 1837. 8vo. London 1837.	The Proprietor.
	The Entomological Magazine for 1837. 8vo. London 1837.	Francis Walker, Esq.
	The Suburban Gardener and Villa Companion, by J. C. Loudon, F.L.S. H.S., &c., nos. 1 to 7, June to Dec. 1837. 8vo. London 1837.	The Author.
	Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, par MM. les Secrétaires perpetuels, for the year 1837. 4to. 1837.	The Academy of Sciences of Paris.
1838.		
Jan. 3.	An Inaugural Address delivered in the Theatre of the Islington Literary and Scientific Society, on the opening of the New Building, Nov. 16th, 1837, by J. J. J. Sudlow, Esq.	The Islington Literary and Scientific Society.
	Journal of the Royal Asiatic Society of Great Britain and Ireland, no. 8, Dec. 1837. 8vo.	The Royal Asiatic Society.
	Remarks on the Geology and Mineralogy of Nova Scotia, by Abraham Gesner, Esq. 8vo. Halifax, Nova Scotia 1836.	The Author.
	Catalogue of the Minerals in the United Service Museum. 8vo. London 1837.	The Council of the United Service Museum.
	N. A. Nattali's Catalogue of Books for 1838. 8vo. London 1838.	Mr. Nattali.
	Essay on the Antiquity of Hindoo Medicine, by J. Forbes Royle, M.D., Professor of Materia Medica in Kings College, London.	The Author.

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Jan.	4.	A System of Geology, with a Theory of the Earth, and an Explanation of its Connexion with the Sacred Records, by John Macculloch, M.D., F.R.S., &c., 2 volumes 8vo. London 1831.	John Willimot, Esq., F.G.S.
		Geognostische Profile, von C. J. E. Freiherrn von Schwerin. 8vo. München 1829.	.....
		Report on the Probability of the Occurrence of Coal and other Minerals in the Vicinity of Lancaster, addressed to the Lancaster Mining Company, by John Phillips, F.R.S., G.S., &c.	The Author.
		Proceedings of the Royal Society of London, no. 30, Nov. 1837. 8vo.	The Royal Society.
		Defence of the Resolution for omitting Mr. Panizzi's Bibliographical Notes from the Catalogue of the Royal Society. 8vo.	.....
		Address to Her Majesty referred to in the Address of His Royal Highness the Duke of Sussex, President of the Royal Society. 8vo.	.....
		The London Medical Gazette, no. 14, containing a Letter by the Rev. W. Whewell on his History of Discoveries in the Nervous System. 8vo.	Rev. Prof. Whewell, Pres. G.S.
		Account of Mr. Whewell's Researches on the Tides. 8vo.	.....
	17.	Elements of Chemistry, including the recent Discoveries and Doctrine of that Science, by the late Edward Turner, M.D., Sixth Edition, enlarged and revised, by Justus Liebig, Professor of Chemistry in the University of Giessen, and Wilton G. Turner, part 2. 8vo. London 1838.	The Editors.
		The Malacological and Conchological Magazine, part 1, conducted by G. B. Sowerby, F.L.S., &c.	The Conductor.
		Rules and Regulations for the government of the Athenæum, with an Alphabetical List of the Members for 1838.	The Athenæum Club.
Feb.	1.	Catalogue des Espèces et Variétés de Mollusques Terrestres et Fluviatiles observés jusqu'à ce jour à l'état vivant dans la Haute et la Basse Auvergne ; suivi d'un autre Catalogue des Espèces Fossiles recueillies récemment dans les diverses Formations Tertiaires des mêmes Départemens, par J. B. Bouillet. 8vo. Clermont Ferrand 1836.	The Author.
		Practical Observations on the Asphaltic Mastic, or Cement of Seyssell, now extensively employed on the Continent for Pavements, Roofing, and Flooring, for Hydraulic Works, &c., by F. W. Simms, Civil Engineer and Sur-	

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	veyor, late of the Royal Observatory, &c. 8vo. London 1837.	The Author.
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	Plates of Dr. Buckland's Bridgwater Treatise, 1836, 4to. edition.	Dr. Buckland.
	Some Account of Two Visits to the Mountains in Essex County, New York, in the years 1836 and 1837, with a Sketch of the Northern Sources of the Hudson, by W. C. Redfield. From the American Journal of Science, vol. 2, no. 33.	The Author.
	A Report of the Geological Survey of Connecticut, by Charles Upham Shephard, M.D. 8vo. New Haven 1837.	The Author.
	The American Journal of Science and Arts, conducted by Benjamin Silliman, M.D., LL.D., &c., vol. 33, no. 2, January. 8vo. New Haven 1838.	The Conductor.
	27. Proceedings of the Zoological Society of London, nos. 49 to 57. 8vo.	The Zoological Society.
	Annales des Mines, ou Recueil de Mémoires sur l'Exploitation des Mines, et sur les Sciences et les Arts qui s'y rapportent, tome 12, cinquième livraison de 1837. 8vo. Paris 1837.	The Council of Mines.
	Considérations sur la Nature des Végétaux qui ont couvert la Surface de la Terre aux diverses Époques de sa Formation, par M. Adolphe Brongniart. 4to. Paris 1838.	The Author.
	Rapport fait à l'Académie des Sciences, par M. de Blainville, sur un Nouvel Envoi de Fossiles, provenant du Dépôt de Sansan, Département de Gers.	The Author.
March	3. Flora Metropolitana, or Botanical Rambles within Thirty Miles of London, being the Results of Excursions in 1833–34–35, more particularly in the Counties of Surrey and Kent, chiefly from actual Observation and the latest Authorities.—With a Supplement containing an Index of both Latin and English Names, Time of Flowering, Colour of Flower, &c., by Daniel Cooper, A.L.S., Curator to the Botanical Society of London, &c. 12mo. London 1837.	The Author.
	Supplement to the Flora Metropolitana, 12mo.	.....

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8.	Proceedings of the Royal Society of London, no. 31, 1837–38. 8vo.	The Royal Society.
10.	Report on the Physical Condition of the Assam Tea Plant, with reference to Geological Structure, Soils, and Climate, by John McClelland, Esq., Assistant Surgeon, Bengal Establishment, and Member of the Asiatic and Medical Societies of Calcutta. Presented to the Agricultural Societies of Calcutta, 8th February, 1837, by desire of Lord Auckland, Governor-General of India. From the Transactions of the Agricultural and Horticultural Society of India, vol. 4. 8vo. 1837.	The Author.
12.	Transactions of the Royal Academy of Berlin, for the year 1835. 4to. Berlin 1836.	The Royal Academy of Berlin.
	Proceedings of the Royal Academy of Berlin from 8th May 1836 to 29th June 1837. 8vo.	.....
15.	The Hunterian Oration, delivered in the Theatre of the Royal College of Surgeons, the 14th Feb. 1838, by Benjamin Travers, F.R.S., &c. &c. 4to. London 1838.	The Author.
17.	Septième Rapport Annuel sur les Travaux de la Société d'Histoire Naturelle de l'Ile Maurice, lu à la Séance Anniversaire du Mercredi, 24 Août 1836, par M. Julien Desjardins, Secrétaire et l'un des Membres Fondateurs de la Société, &c. 8vo.	The Author.
	Liste des Membres qui composent la Société d'Histoire Naturelle de l'Ile Maurice, 1er Septembre 1836. 8vo.	M. Julien Desjardins.
24.	Madras Journal of Literature and Science, published under the auspices of the Madras Literary Society and Auxiliary Royal Asiatic Society; edited by the Secretary to the Asiatic Department; nos. 15, 16, 17, for April, July, and October 1837. 8vo. Madras 1837.	The Madras Literary Society.
	Catalogo delle Collezioni Orittologica ed Oreognostica, del fu Professore Cav. Matteo Tondi, Direttore del Museo di Mineralogia di Napoli, Professore di Orittologia ed Oreognosia nella Regia Università degli Studj, &c. &c. 8vo. Napoli 1837.	J. B. Heath, Esq.

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	The Wonders of Geology, by Gideon Mantell, LL.D., F.R.S., in two volumes, 12mo. London 1838.	The Author.
Apr. 6.	Address to the Members of the Berwickshire Naturalists' Club after the Sixth Anniversary Meeting, held at Norham, Sept. 20th, 1837, by the Rev. John Bird of Yetholm, President. 8vo.	The Berwickshire Naturalists' Society.
	The Journal of the Royal Geographical Society of London, vol. 8, part 1. 8vo. London 1838.	The Royal Geographical Society.
	Journal of the Geological Society of Dublin, vol. 1, parts 2 and 3. 8vo. Dublin.	The Geological Society of Dublin.
	Notice sur la Famille des Bulléens dont on trouve les dépouilles Fossiles dans les Terrains Marins supérieurs du Bassin de l'Adour, aux Environs de Dax (Landes), précédée de Considérations Générales sur cette Famille et du Tableau des Genres et des Espèces connus, soit à l'état Vivant, soit à l'état Fossile, par M. le Docteur Grateloup. 8vo. Bourdeaux 1837.	The Author.
	Discours sur les Sciences et sur les Arts, et sur l'influence qu'ils exercent sur les progrès de la civilisation, prononcé à la Séance Publique de l'Académie Royale des Sciences de Bourdeaux, par M. le Docteur Grateloup. 8vo. Bourdeaux 1837.	.....
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	Memoir of the late President of the Royal Irish Academy, by the Rev. J. H. Singer, D.D., Secretary of the Academy. 8vo. 1838.	.....
May 1.	Bulletin de la Société Géologique de France, tome 9, feuilles 6–9. 8vo. Paris 1838.	The Geological Society of France.

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	Transactions of the Historical and Literary Committee of the American Philosophical Society, held at Philadelphia, for promoting Useful Knowledge, vol. 2. 4to. Philadelphia 1838.	The American Philosophical Society.
	The Zoology of the Voyage of H. M. S. Beagle, under the command of Captain Fitzroy, during the years 1832–36. Published with the Approval of the Lords Commissioners of Her Majesty's Treasury. Edited and superintended by Charles Darwin, Esq., M.A., F.G.S., &c. No. 1, part 2.—Mammalia, by George R. Waterhouse, Esq. 4to. London 1838.	C. Darwin, Esq., Sec. G.S.
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	Mémoires de la Société de Physique et d'Histoire Naturelle de Genève, tome 8, première partie. 4to. Genève 1838.	The Natural History Society of Geneva.
	Bulletin de la Société Géologique de France, tome 9, feuilles 10–14. 8vo. Paris 1838.	The Geological Society of France.
	Proceedings of the Numismatic Society, 1836–37. 8vo.	The Numismatic Society.
	Second Report of the Geology of the State of Maine, by Charles T. Jackson, M.D. 8vo. Augusta, 1838.	The Author.
	Fifteenth Report of the Whitby Literary and Philosophical Society, presented at the Annual Meeting, Oct. 31, 1837, with a List of the Officers and Members, and of Donations presented to the Museum. 8vo. Whitby 1837.	The Whitby Literary Society.
	Eighth Report of the Scarborough Philosophical Society, to Aug. 31, 1837. Scarborough 1837.	The Scarborough Philosophical Society.
June 6.	Transactions of the Society of Arts, Manufactures, and Commerce, vol. 51, part 2. 8vo. London 1838.	The Society of Arts.
	Programma da Real Academia das Sciencias de Lisboa, annunciado na Sessão Publica de 15 de Maio de 1838, para o Anno de 1839.	The Lisbon Academy.
	Ascent to the Summit of Mont Blanc on the 22nd and 23rd of August, 1837, by Henry Martin Atkins, Esq.	The Editor, through John Kenyon, Esq., F.G.S.
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	Annual Report of the Council of the Yorkshire Philosophical Society for 1837. 8vo. York 1838.	The Yorkshire Philosophical Society.
	Fifth Annual Report of the Royal Cornwall Polytechnic Society, 1837. 8vo. Penzance 1838.	The Royal Cornwall Polytechnic Society.

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	Journal of the Royal Geographical Society of London, vol. 8, part 2. 8vo. London 1838.	The Royal Geographical Society of London.
	Address to the Royal Geographical Society of London, delivered at the Anniversary, 21st May, 1838, by William R. Hamilton, Esq., F.R.S., President. 8vo. London 1838.	The Author.
	Notizie intorno a due Fossili trovati nei Colli di San Stefano Roero, del Professore Angelo Sismonda. 4to. Torino 1838.	The Author.
	Osservazioni Geologiche e Mineralogiche sopra i Monti posti tra la Valle di Aosta e quella di Susa in Piemonte, del Professore di Mineralogia, Angelo Sismonda. 4to. Torino 1838.	.....
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7.	The Zoology of the Voyage of His Majesty's Ship Beagle, under the command of Captain Fitzroy, R.N., during the years 1832 to 1836. no. 1 of part 3, Birds, by John Gould, Esq., F.L.S., &c. 4to. London 1838.	C. Darwin, Esq., Sec. G.S.
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	Society for the Encouragement of Arts, Manufactures, and Commerce. Premiums for the Sessions 1838–1839 and 1839–1840. Six copies. 8vo. London 1838.	The Society for the Encouragement of Arts, &c.
	Proceedings of the Royal Irish Academy for the year 1837–1838, part 2, nos. 12 and 13. 8vo.	The Royal Irish Academy.
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	List of Members of the British Association for the Advancement of Science, to which are added, a List of the Officers, Rules of the Association, and Contents of the Reports already published. 2 copies. 8vo. London 1838.	The British Association for the Advancement of Science.
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	Essai sur les Soulèvemens Jurassiques, second cahier, contenant la Carte Orographique et Géologique des Soulèvemens du Jura Bernois, accompagnée d'une Description Systématique, par J. Thurmann. 4to. Porrentruy 1836.	The Author.
	Geognostiche Wanderungen, von Bernhard Cotta. 2 Theile. 8vo. Dresden und Leipzig 1838.	C. Lyell, Esq., V.P.G.S.
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	Madras Journal of Literature and Science, no. 18, January to March 1838. 8vo. Madras 1838.	Madras Literary Society.
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	Göttingische gelehrte Anzeigen, unter der Aufsicht der Köngigl. Geselschaft der Wissenschaften, nos. 6—9, 1837; 146, 147, 1837, and 14, 15, 1838. 12mo. Göttingen 1837–1838.	.....
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	Geognostiche Wanderungen, von Bernhard Cotta. 2 Theile. 8vo. Dresden und Leipzig 1838.	The Author.
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31.	Observations on the Genus Unio, together with Descriptions of New Genera and Species in the Families Naiades, Colimacea, Lymnæana, Melaniana, and Peristomiana, by Isaac Lea, Esq., Mem. of the American Phil. Soc., &c., vol. 2. 4to. Philadelphia.	The Author.
	State of New York, no. 200, in Assembly, Feb. 20, 1838. Communication from the Governor relative to the Geological Survey of the State. With Plates, detached. 8vo. Albany 1838.	Professor Vanuxem and Mr. Conrad.
Sept. 3.	The Zoology of the Voyage of H. M. Ship Beagle, under the command of Capt. Fitzroy, R.N., during the years 1832 to 1836, published with the approval of the Lords Commissioners of the Treasury; edited and superintended by Charles Darwin, Esq., Sec. G.S., &c. Mammalia, by Geo. R. Waterhouse, Esq., Curator of the Zoological Society of London; no. 2 of part 2. 4to. London 1838.	Charles Darwin, Esq., Sec. G.S.
4.	Transactions of the Linnean Society of London, vol. 18, part 1, with a List of the Society, 1838. 4to. London 1838.	The Linnean Society.
	Lethæa Geognostica, 9te Lieferung (Bogen 49–60) als Rest. pp. 769 to 960, von H. G. Bronn. 8vo. Stuttgart.	The Author.
	The American Journal of Science and Arts, conducted by Benjamin Silliman, M.D., LL.D., aided by Benjamin Silliman, jun., A.B. vol. 34, no. 2, July 1838. 8vo. Newhaven 1838.	The Conductors.
8.	The Journal of the Royal Asiatic Society of Great Britain and Ireland, no. 9, August 1838. 8vo. London 1838.	The Royal Asiatic Society.
	Royal Asiatic Society, Proceedings of the Committee of Agriculture and Commerce; note by the Chairman at a Meeting of the Committee held on the 24th May 1838. 8vo. London 1838.	.....

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	Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, aus dem Jahre 1836. 4to. Berlin 1838.	The Royal Academy of Berlin.
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20.	Report of the Seventh Meeting of the British Association for the Advancement of Science, held at Liverpool in September 1837. 8vo. London 1838.	The British Association.
21.	Transactions of the American Philosophical Society held at Philadelphia for promoting Useful Knowledge, new series, vol. 6, part 1. 4to. Philadelphia 1838.	American Phil. Society.
	Annales des Mines, ou Recueil de Mémoires sur l'Exploitation des Mines et sur les Arts qui s'y rapportent, troisième série, tome 13, 3 livraison de 1838. 8vo. Paris 1838.	L'Administration des Mines.
28.	Mémoire sur les Rochers Calcaires innombrables épars dans les Environs de la Roche, et jusqu'au lit de l'Arve, et sur les Blocs de Granit qui les accompagnent, par J.-A. De Luc. 4to.	The Author.
Oct. 3.	The Economy of a Coal Field; an Exposition of the Objects of the Geological and Polytechnic Society of the West Riding of Yorkshire, and of the best means of attaining them, by James F. W. Johnston, M.A., F.R.SS. L. and E. 8vo. Durham 1838.	The Author.
6.	Allen's Select List of Publications. 12mo. London 1838.	Messrs. Allen and Co.
	Mémoires couronnés par l'Académie Royale de Bruxelles, tomes 5, 6, 7, 8, 9, 10, 11, 12, 13. fol. Bruxelles 1824—1838.	The Royal Academy of Brussels.
	Nouveaux Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles, tome 10. fol. Bruxelles 1836–1837.	.....
	Annales de l'Observatoire de Bruxelles publiés aux frais de l'État, par le Directeur, A. Quetelet, tome 1, deuxième partie. 4to. Bruxelles 1837.	.....
	Bulletin de l'Académie Royale de Bruxelles de la Séance du 4 Novembre 1837, jusqu'à la Séance du 4 Août 1838. 8vo. Bruxelles 1837–1838.	.....
	Annuaire de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles, 1836–37–38. 18mo. Bruxelles 1836–38.	.....
7.	Royal Geological Society of Cornwall, Twenty-fifth Annual Report of the Council. 8vo. Penzance 1838.	Royal Geological Society of Cornwall.
	The Analyst; a Quarterly Journal of Science, Litera-	

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	Lethæa Svecica, seu Petrificata Sveciæ, Iconibus et Characteribus illustrata a W. Hisinger. 4to. Holmiæ 1837.	The Author.
	Mémoires de la Société Géologique de France, tome troisième, première partie. 4to. Paris 1838.	Geological Society of France.
	Annual Report of the Leeds Philosophical and Literary Society for 1837–38. 8vo. Leeds 1838.	Leeds Philosoph. Society.
26.	Discurso lido em 15 de Maio de 1838, na Sessão publica da Academia Real das Sciencias de Lisboa, por Joaquim José da Costa de Macedo.	The Royal Lisbon Academy.
27.	Verhandlungen der Gesellschaft des vaterländischen Museums in Böhmen in der sechszehnten allgemeinen Versammlung, am 18 April 1838. 8vo.	The Society of the Fatherland Museum of Bohemia.
Dec. 2.	A List of Members of the Royal College of Surgeons in London. 8vo. London 1838.	The Royal College of Surgeons.
5.	The Zoology of the Voyage of H. M. Ship Beagle, under the command of Captain Fitzroy, during the years 1832 to 1836, edited and superintended by Charles Darwin, Esq., M.A., Sec. G.S., &c. Mammalia, by George Waterhouse, Esq., no. 3 of part 2. 4to. London 1838.	Charles Darwin, Esq., Sec. G.S.
	Annales des Mines, ou Recueil de Mémoires sur l'Exploitation des Mines et sur les Sciences et les Arts qui s'y rapportent, rédigées par les Ingénieurs des Mines, troisième série, tome 14, 4ième livr. de 1838. 8vo. Paris.	L'Administration des Mines.
	List of the Linnean Society of London, 1838. 4to. London 1838.	Linnean Society.
	Transactions of the Cambridge Philosophical Society, vol. 6, part 1. 4to. Cambridge.	Cambridge Philosophical Society.
	Del Sollevamento e dell' Avvallamento di alcuni Terreni, Discorso di D. Paoli. 8vo. Pesaro 1838.	The Author.
	Antonii Bertoloni, M.D., Commentarius de itinere Neapolitano, æstate anni 1834 suscepto. 8vo. Bononiæ 1837.	Il Sig. Tenore.

1838.	BOOKS.	DONORS.
Dec. 5.	Essai sur la Statistique Générale de la Belgique, composé sur des Documents publics et particuliers, par Xavier Heusehling, Premier Commis au Ministère des Finances, et publié par Ph. Van der Maelen, Fondateur de l'Établissement Géographique de Bruxelles. 12mo. Bruxelles 1838.	M. Van der Maelen, F.G.S.
	Catalogue Général de l'Établissement Géographique de Bruxelles, fondé par Ph. Van der Maelen.	.....
	The Journal of the Geographical Society of London, vol. 8, part 3, 1838. 8vo. London 1838.	The Geographical Society of London.
	Transactions of the Zoological Society of London, vol. 2, part 2. 4to. London 1838.	The Zoological Society.
	Proceedings of the Zoological Society of London, from Oct. 10th, 1837, to July 10th, 1838. 8vo.	.....
17.	The American Journal of Science and Arts, conducted by Benjamin Silliman, M.D., L.L.D., &c., For. Mem. G.S., &c., aided by Benjamin Silliman, junr., A.B., vol. 35, no. 1, October 1838. 8vo. New Haven.	The Conductors.
	Bulletin de la Société Géologique de France, tome 9, feuilles 15 à 19 et 20 à 22. 8vo.	The Geological Society of France.
20.	Instructions pour l'Exploration Géologique de l'Algérie, rédigées par M. Elie de Beaumont, adoptées par l'Académie des Sciences, le 19 Mars 1838. 4to; et Instructions pour les Géologues de l'Expédition qui se rend dans le Nord de l'Europe, rédigées par M. Elie de Beaumont. 4to.	The Author.
	Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, par MM. les Secrétaires Perpetuels, for 1838. 4to. Paris 1838.	The Academy of Sciences of Paris.
	Arboretum et Fruticetum Britannicum, by J. C. Loudon, Esq., F.L.S., the numbers published during 1838. 8vo. London 1838.	The Author.
	The Magazine of Natural History, new series, conducted by Edward Charlesworth, Esq., F.G.S., formerly by J. C. Loudon, Esq., F.L.S., &c., for 1838. 8vo. London 1838.	The Conductor.
	The London and Edinburgh Philosophical Magazine and Journal of Science, conducted by Sir David Brewster, K.H., LL.D., F.R.S. L. and E., &c., Richard Taylor, Esq., F.S.A., L.S., G.S., &c., and Richard Phillips, Esq., F.R.S. L. and E., F.G.S., &c., for 1838. 8vo. London 1838.	Rich. Taylor, Esq., F.G.S.
	The Repertory of Patent Inventions, and other Discoveries and Improvements in Arts, Manufactures, and Agriculture, for 1838. 8vo. London 1838.	The Proprietor.

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Dec. 20.	Observations on Limes, calcareous Cements, &c., by Col. C. W. Pasley, R.E., F.G.S.	The Author.
	Dictionnaire Géographique du Luxembourg, par M. Ph. Vander Maelen.	The Author.
1839.		
Jan. 9.	The Silurian System, founded on Geological Researches in the counties of Salop, Hereford, &c., by Roderick Impey Murchison, Esq., F.G.S., &c.	The Author.
	Instructions pour les Géologues de l'Expédition qui se rend dans le Nord de l'Europe, rédigées par M. Elie de Beaumont. 4to. Paris 1838.	M. Elie de Beaumont, For. Mem. G.S.
	Instructions pour l'Exploration Géologique de l'Algérie, rédigées par M. Elie de Beaumont. 4to. Paris.	.....
	The Zoology of the Voyage of H. M. Ship Beagle, under the command of Captain Fitzroy, R. N., during the years 1832 to 1836, edited and superintended by Charles Darwin, Esq., Sec. G.S. no. 2, part 3. 4to. London 1839.	Charles Darwin, Esq., Sec. G.S.
	Proceedings of the Royal Society, no. 35. 8vo.	The Royal Society.
	Mr. A. Nattali's Catalogue of Books for 1839. 8vo. London 1839.	Mr. Nattali.
	Lethœa Geognostica, von G. H. Bronn, p. 481 to end. 8vo. plates 4to. Stuttgart 1838.	The Author.
	A Sketch of the Geology of Fife and the Lothians, including detailed descriptions of Arthur's Seat and Pentland Hills, by Charles Maclaren, Esq., F.R.S.E. 12mo. Edinburgh 1839.	The Author.
	Monographia Chalciditum, by Francis Walker, Esq. 8vo. London 1839.	The Author.
	Memoirs of the Royal Astronomical Society, vol. 10. 4to. London 1839.	The Royal Astronomical Society.
	Observations on some new Organic Remains in the Flint of Chalk, by the Rev. J. B. Reade, M.A., F.R.S., 8vo. London 1838.	The Author.
Feb. 1.	Memoirs of the Wernerian Society, vol. 4, parts 1 and 2; vol. 5, part 1; and vol. 7. 8vo. Edinburgh.	The Wernerian Society.
	Elements of Chemistry, including the recent Discoveries and Doctrines of the Science, by the late Edward Turner, sixth edition, enlarged and revised by Justus Liebig, Ph. D., and Wilton John Turner, Ph. D. Part 3, no. 1, Organic Chemistry, by Professor Liebig. 8vo. London 1839.	Wilton John Turner, Esq.
	Report on the Geology of Cornwall, Devon, and West Somerset, by H. T. De la Beche, Esq., F.R.S., &c., Director of the Ordnance Geological Survey; published	The Lords Commissioners

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	by order of the Lords Commissioners of Her Majesty's Treasury. 8vo. London 1839.	of Her Majesty's Treasury.
Feb.	1. Address to the Members of the Berwickshire Naturalists' Club, delivered at the Anniversary Meeting held at Ford, 19th September, 1838, by Dr. Clarke, President. 8vo.	The Berwickshire Naturalists' Club.
	Institution of Civil Engineers, Annual Report. Session 1839. 8vo.	The Institution of Civil Engineers.
	Annales des Mines, troisième série, tome 14, 5e livraison, 1838. 8vo. Paris 1838.	L'Administration des Mines.
	Lehrbuch der Geognosie und Geologie von Karl Cäsar v. Leonhard, mit Abbildungen. 8vo. and plates 4to. Stuttgart 1835.	Rev. Wm. Bilton, F.G.S.
	Charts, Sailing Directions, and Tide Tables, published by direction of the Lords Commissioners of the Admiralty. 8vo. and 4to. 1838.	Capt. Beaufort, R.N., Hon. Mem. G.S., by direction of the Lords Commissioners of the Admiralty.
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	A Conchological Manual, by G. B. Sowerby, jun. 8vo. London 1839.	The Author.
	Illustrazione di un Nuovo Cetaceo Fossile proposta dal Medico Giounni Domenico Bruno. 4to.	The Author.
	Bulletin de la Société Géologique de France, tome 9, feuilles 23–27. 8vo. Paris 1838.	The Geological Society of France.
	American Journal of Science and Arts, conducted by Dr. Silliman, For. Mem. G.S. vol. 32, no. 2. 8vo. New Haven 1838.	The Conductor.
	On the Courses of Hurricanes, with Notices of the Typhoons of the China Sea, and other Storms, by W. C. Redfield, Esq. From the American Journal of Science and Arts, no. 2, vol. 25.	The Author.
	Observations on Roman Coin Moulds discovered in England and France. From the 3rd no. of the Numismatic Chronicle. 8vo. London 1839.	The Author.
	Rapport sur les Travaux de la Carte Géologique, pendant l'année 1838, par A. H. Dumont. 12mo. Extrait du tom. 5 des Bull. Acad. Roy. de Bruxelles.	The Author.
March	. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, aus dem Jahre 1836. 4to. Berlin 1838.	The Royal Academy of Berlin.
	———— aus dem Jahre 1833. 4to. Berlin.	.....
	Illustrations of the Botany and other Branches of the Natural History of the Himalayan Mountains, and of the Flora of Cashmere, by J. Forbes Royle, M.D., V.P.R.S., F.G.S., &c. &c., part 10. 4to. London.	The Author.

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March	. The Zoology of the Voyage of H. M. Ship Beagle, under the command of Captain Fitzroy, R.N., during the years 1832 to 1836, edited by Charles Darwin, Esq., M.A., F.R.S., &c., Naturalist to the Expedition. No. 2 of part 1, Fossil Mammalia, by Richard Owen, Esq., F.R.S., &c. 4to. London 1839.	Charles Darwin, Esq., Sec. G.S.
	Lectures on Comparative Anatomy, delivered in the University of London during 1833, by Robert E. Grant, M.D., &c., Professor of Comparative Anatomy and Zoology in the University of London. Taken in short-hand writing from his oral demonstrations, and published in the Lancet for 1833–34. 8vo.	Professor Grant, M.D. F.G.S.
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	On the Foot-marks of Cheirotherium in the New Red Sandstone of Stourton Hill, by Dr. Grant. (From the Liverpool Mercury, August 24, 1838.)	.....
12.	Philosophical Transactions of the Royal Society of London for the year 1838, part 2. 4to. London 1839.	The Royal Society.
	Proceedings of the Royal Society of London, no. 36.	.....
13.	Bulletin de la Société Géologique de France, tome 10, feuilles 1–4. 8vo.	The Geological Society of France.
	Emanuelis Swedenborgii Opera Philosophica et Mineralogica. Tres tomi fol. Dresdæ et Lipsiæ 1734.	Leonard S. Coxe, Esq., F.G.S.
18.	Nouveaux Mémoires de l'Académie Royale des Sciences et Belles Lettres de Bruxelles, tome 11. 4to. Bruxelles 1838.	The Royal Academy of Brussels.
	Mémoires couronnés par l'Académie Royale des Sciences et Belles Lettres de Bruxelles, tome 11 et 14. 4to. Bruxelles 1837, 1838.	.....
	Bulletin de l'Académie Royale des Sciences et Belles Lettres de Bruxelles, 1838, nos. 9—12. 8vo. Bruxelles.	.....
	Annuaire de l'Académie Royale des Sciences et Belles Lettres de Bruxelles, 1839, 5ième année. 18mo. Bruxelles.	.....
	Proceedings of the Royal Irish Academy, no. 15, 1839. 8vo.	The Royal Irish Academy.
	Royal Asiatic Society of Great Britain and Ireland, Proceedings of the Committee of Commerce and Agriculture, 1838. 8vo. London 1839.	The Committee of Commerce and Agriculture of the Asiatic Society.
	First Report on the Geological Survey of the Province of New Brunswick, by Abraham Gesner, Provincial Geologist, &c., 1839. 8vo. Saint John 1839.	The Author.

1839.	BOOKS.	DONORS.
March 18.	The Journal of the Royal Geographical Society of London, vol. 9, part 1. 8vo. London 1839.	The Royal Geographical Society.
	Buenos Ayres and the Provinces of the Rio de la Plata, by Sir Woodbine Parish, K.C.H., F.R.S., F.G.S., &c. 8vo. London 1839.	The Author.
26.	Proceedings of the Botanical Society of London, vol. 1, part 1. 8vo. London 1839.	The Botanical Society of London.
	A Treatise on Crystallography, by W. H. Miller, M.A., F.R.S., F.G.S., F.C.P.S., Fellow and Tutor of St. John's College, and Professor of Mineralogy in the University of Cambridge. 8vo. Cambridge 1839.	The Author.
27.	Outlines of Comparative Anatomy, by Robert E. Grant, M.D., F.R.S., F.G.S., &c., parts 1—4; and Essays on Zootomical Subjects, by Robert E. Grant, M.D. 8vo. London.	The Author.
30.	Classification of the Older Stratified Rocks of Devonshire and Cornwall, by the Rev. Professor Sedgwick, F.R.S., F.G.S., and Roderick Impey Murchison, Esq., F.R.S., F.G.S. From the Philosophical Magazine, vol. 14. 8vo. London 1839.	The Authors.
	Dictionnaire Géographique de la Province de Limbourg; Établissement Géographique de Bruxelles, fondé par Ph. Vander Maelen. 8vo. Bruxelles 1835.	M. Vander Maelen, F.G.S.
April 2.	Ninth Report of the Scarborough Philosophical Society, August 31, 1838. 8vo. Scarborough 1838.	The Scarborough Philosophical Society.
3.	The Naturalist; illustrative of the Animal, Vegetable, and Mineral Kingdoms; edited by Neville Wood, Esq.; nos. 8—12 of vol. 2; 17—19 and 23 of vol. 3; and 25, 26, and 29 of vol. 4. 8vo. London 1835–38.	The Editor.
	Annales des Mines, ou Recueil de Mémoires sur l'Exploitation des Mines, et sur les Sciences et les Arts qui s'y rapportent; rédigées par MM. les Ingénieurs des Mines; troisième série, tome 14, 6e livraison de 1838. 8vo. Paris 1838.	L'École des Mines.
15.	Bulletin de la Société Géologique de France, tome 9, feuilles 28–32. 8vo.	The Geological Society of France.
May 1.	Journal of the Geological Society of Dublin, vol. 1, part 4. 8vo. Dublin 1838.	The Geological Society of Dublin.
4.	The Zoology of the Voyage of H. M. Ship Beagle, under the command of Capt. Fitzroy, R.N., during the years 1832 to 1836; edited and superintended by Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. No. 3 of part 1, Fossil Mammalia, by Richard Owen, Esq., F.R.S., F.G.S., &c. 4to. London 1839.	Charles Darwin, Esq., Sec. G.S.
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	Carbonic Acid Gas, near Kissingen, in Bavaria, by Professor Forbes, F.G.S. From the Edinburgh New Philosophical Journal, no. 52. 8vo. Edinburgh 1839.	The Author.
May	4. Foreign Monthly Review, and Continental Literary Journal, no. 1, May 1839. 8vo. London 1839.	The Publisher.
	Proceedings of the American Philosophical Society, vol. 1, no. 6. 8vo. Philadelphia 1838.	The American Philosophical Society.
	Report of the Local Secretaries of the Meeting of the British Association at Newcastle. 8vo. Newcastle 1839.	J. F. W. Johnston, Esq.
	Bulletin de la Société Géologique de France, tome 10, feuilles 5 à 9. 8vo.	The Geological Society of France.
	Conchyliologie Fossile du Basin de l'Adour, 4e et 5e Mémoires, et Tableau Statistique des Coquilles Univalves Fossiles trouvées dans les Couches Tertiaires du Basin de l'Adour, par M. le Docteur Grateloup. 8vo. Bordeaux 1838.	The Author.
	22. Researches on the Development, Structure, and Diseases of the Teeth, by Alexander Nasmyth, Esq., F.L.S., F.G.S. 8vo. London 1839.	The Author.
	Proceedings of the Royal Irish Academy, no. 16, 8vo., and a List of the Members. 8vo. Dublin 1838.	Royal Irish Academy.
	31. Reply to Professor Bischoff's Objections to the Chemical Theory of Volcanos, by Charles Daubeny, M.D., &c. 8vo.	Dr. Daubeny.
June	2. Wonders of Geology, by Gideon Mantell, LL.D., F.R.S., 3rd edit. 12mo. London 1839.	The Author.
	The London and Edinburgh Philosophical Magazine and Journal of Science, conducted by Sir David Brewster, K.H., LL.D., F.R.S. L. & E., &c., Richard Taylor, Esq., F.S.A., L.S., G.S., &c., and Richard Phillips, Esq., F.R.S. L. & E., F.G.S., &c.; for the months of January to June 1839. 8vo. London 1839.	Richard Taylor, Esq., F.G.S.
	The Repertory of Patent Inventions, and other Discoveries and Improvements in Arts, Manufactures, and Agriculture, for the months of January to June 1839. 8vo. London 1839.	The Proprietor.
	The Magazine of Natural History, New Series, conducted by Edward Charlesworth, F.G.S., &c.; for the months of January to June 1839. 8vo. London 1839.	The Conductor.
	Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, par MM. les Sécrétaires perpetuels, Premier Semestre; January to June 1839. 4to. Paris 1838.	The Academy of Sciences of Paris.

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	Le Pilote de l'Ile de Corse; 32 cartes et plans en feuilles.	.....
	Description Nautique des Côtes de la Martinique; 20 cartes et plans en feuilles.	.....
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	A rough Sketch, by Nöggerath, of the part of the Eifel between Adenau and Wittich.	Lieut. Nelson, R.E.
Dec. 2.	Arrowsmith's Map of La Plata, the Banda Oriental, and Chile.	W. Parish, Esq. Sec. G.S.
	Carte Géologique du Département de la Manche, dressée en 1825, 1826, 1827, par M. A. de Caumont.	M. A. de Caumont.
	A specimen plate, illustrative of Natural History, by Mr. G. B. Sowerby, jun.	Mr. G. B. Sowerby, jun.
	Six Views in the Zoological Gardens, by Mr. Scharf.	Mr. Scharf.
16.	A Portrait of Sir F. W. J. Herschel, M.A., F.R.S., G.S., &c.	Rev. R. Sheepshanks, F.G.S.
1836.		
Jan. 20.	An Impression of a Lithographic Drawing of a Fossil Turtle, in a Nodule of Harwich Cement Stone.	Edw. Charlesworth, Esq., F.G.S.
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	14.	An Impression of an Engraving of *Dentalium Saturni* (Hœninghaus), discovered in the Transition Limestone of Gerolstein.	M. F. W. Hœninghaus.
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	11.	Map, Section, and Book of Reference of the intended Midland Counties Railway.	Thos. Edw. Dicey, Esq.
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1837.			
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	niart, Professor of Mineralogy in the Museum of Natural History, Paris.	M. Alex. Brongniart, For. Mem. G.S.
May	3. Tabular View of the Distribution of the characteristic Organic Remains of the Jura Limestone in Germany, by Leopold de Bach, For. Mem. G.S.	M. Leopold de Bach, For. Mem. G.S.
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	An impression from an Engraving of a Portrait of Dr. Mantell.	Mr. Samuel Stepney.
1838.		
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	Admiralty Charts, Sailing Directions, and Tide Tables, published during the year 1837.	Capt. Beaufort, R.N., Hon. Mem. G.S., by order of the Lords Commissioners of the Admiralty.
May	1. Map of the Maritime County of Mayo in Ireland, on various Bases and Trigonometrical Operations, exhibiting Barometrical Observations of the Mountains, the Levels, and Depths of the Bogs and Lakes, with Astronomical Observations, Physical Sections, and Profiles of the Country; executed by order of the Grand Jury, and terminated in 1817, by William Bald, F.R.S.E., M.R. Geog. Soc., Paris, F.G.S., M.R.I.A.	William Bald, Esq., F.G.S.
June to *Nov.*	1. Sheets 49, 50, 66, 67, 68, 72, of the Ordnance Map, in continuation of the Trigonometrical Survey of Great Britain.	The Master-General and Board of Ordnance.
July	28. Sheet 10 of the Geological Map of the Kingdom of Saxony.	The Council of Mines of Saxony.
Oct.	24. Two Lithographic Impressions of a Drawing of *Pentacrinites Briareus* and of the *Palo de Vaca*, or Cow Tree, from an original sketch by Sir R. Ker Porter; litho-	

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Nov.	6.	Map of the settled part of the colony of New South Wales, showing the situation of the principal rocks, by Major T. L. Mitchell, F.G.S.	MajorT.L. Mitchell, F.G.S.
1839.			
Jan.		Fourth sheet of the Geological Map of Saxony.	The Council of Mines of Saxony.
		Geological Map of Germany and the neighbouring States, and Geological Map of the N.W. of Germany, by Friedrich Hoffmann.	Rev. Prof. Whewell, P.G.S.
Feb.	16.	Map of the Silurian region and adjacent counties of England and Wales geologically illustrated, by Roderick Impey Murchison, Esq., F.G.S., (mounted and framed).	R.I.Murchison, Esq., F.G.S.
April	2.	Lithographic Print of the *Orthagoriscus Mola* or Sun Fish, washed ashore at Scarborough during a gale on the 27th November, 1838. The original in the Scarborough Museum.	Edw. Hebden, Esq., on the part of the Scarborough Museum.
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		Rock specimens from Teneriffe.	.....
		A collection of specimens from the Virgin Islands, made at the request of the Royal Geographical Society of London, by Robert Schomburgk, Esq.	The Royal Geographical Society.
Aug.	14.	A collection of specimens from the Cerro de Pasco, made by Don Mariano Rivero.	Don Mariano Rivero.
	25.	Specimens from Beauvais.	Gideon Mantell, Esq., F.G.S.
		Fossils from the inferior oolite of Leckhampton Hill, near Cheltenham.	Capt. Mudge, R.E., F.G.S.
		Additional specimens from the strata between the chalk and the Oxford oolite, in the south-east of England.	W. H. Fitton, M.D., F.G.S.
Sept.	5.	Fossils from Malta.	— Collins, Esq.
		Fossils from the chalk at Gravesend.	Joseph Prestwich, jun., Esq., F.G.S.

1835.		SPECIMENS.	DONORS.
Sept.	22.	Specimens from the newer pliocene beds in the neighbourhood of Brighton.	GideonMantell,Esq.,F.G.S.
	26.	Specimens of fishes from the chalk.	.....
Oct.	6.	*Ammonites perarmatus* and fossils from the chalk, upper green-sand, &c.	J. Kenyon, Esq., in the name of the late Mrs. Kenyon.
		Fossils and flints from the chalk.	R. Cuming, Esq.
		Fossils from the gault of Neuchatel, Switzerland.	Professor Agassiz.
		Specimens from the Rhine.	Lieut. Nelson, R.E.
	14.	Fossils from Cerigo.	Lord Nugent.
		Fossils from Blackdown and Wiltshire.	Miss Benett, of Norton House.
		A specimen from the plastic clay near Chatham.	G. S. Nicholson, Esq., F.G.S.
		A slab of new red sandstone with impressions of fish, from Rhone Hill, near Dungannon.	Thomas Green, Esq.
Nov.	1.	Specimens from the gravel of Bollingdon Hill, Essex.	John Brown, Esq., F.G.S.
		Specimens of vegetable remains from the coal-mines at Sydney, Cape Breton.	J. B. Ford, Esq.
	24.	Fossil fishes from the coal-measures at Wardie near Newhaven, Stoney Hill near Musselburgh, and the Edmonstone Colliery near Stoney Hill.	Major-General Lord Greenock, F.G.S.
		Specimens from the chalk of Beachy Head, and from the Hastings Beach.	Woodbine Parish, Esq., Sec. G.S.
	27.	Specimens from the chalk of Hemel Hempstead.	H. C. White, Esq., F.G.S.
		Fossils from Blackdown and Bognor.	Miss Benett, of Norton House.
		Remains of a recent sheep imbedded in indurated clay.	Messrs. Francis, White, and Francis.
Dec.	5.	Fossils from the limestone shale of Pembrokeshire.	Earl of Cawdor, F.G.S.
	8.	Specimens of selenite from the sands of the plastic clay at Bishopstone Cliff, between Herne Bay and Reculvers.	W.Richardson,Esq., F.G.S.
1836.			
Jan.	6.	Fossils from Cornwall.	H. T. De la Beche, Esq., For. Sec. G.S., in the name of the Ordnance Geological Survey.
		Fossils from the neighbourhood of Bodmin.	Dr. Potts.
		Specimen of earthy phosphate of iron from Boyland, near Long Stratton, Norfolk.	S. Woodward, Esq.
		Specimens of syenite from veins traversing mica slate and chalk near Goodland Cliff and Torr Eskert, to the south of Fair Head, Antrim.	Rich. Griffith, Esq., F.G.S.
		Fossils from the strata below the chalk in Buckinghamshire and Oxfordshire.	W. H. Fitton, M.D., F.G.S.
	20.	Fossils from the lower limestone shale and the upper Silurian beds of Pembrokeshire.	Earl of Cawdor, F.G.S.

1836.		SPECIMENS.	DONORS.
Jan.	20.	Fossils from Bognor.	James Laird, M.D., F.G.S.
		Specimens of sandstone, with impressions of plants, from the neighbourhood of Whitfield.	Rev. Archdeacon Scott, F.G.S.
		Fossils from Van Diemen's Land.	Richard W. Hay, Esq.
		Fossil plants from the coal-measures at Barnsley, Yorkshire.	W. Taylor, Esq., F.G.S.
Feb.	3.	Specimens from the Island of Ascension.	Mrs. Warren, in the name of the late Dr. Warren.
		Fossils from the neighbourhood of Cheltenham.	Capt. Mudge, R.E., F.G.S.
	20.	Specimen of bone breccia and fossils from Cerigo.	Lord Nugent.
	23.	Large fragment of bone from the base of the diluvial cliffs near Southwold, Suffolk.	Edw. Charlesworth, Esq., F.G.S.
		Cast of the united atlas and axis of an Ichthyosaurus.	Sir Philip Grey Egerton, Bart., M.P., F.G.S.
Mar.	10.	Mesotype from Mount Ecchio, near Verona.	James Yates, Esq., F.G.S.
		Petrified wood, with hazel nuts, from a sub-marine forest and bog on the Irish coast, described in the Geological Transactions, vol. 4, p. 443.	.....
		Remains of the mastodon, mammoth, hippopotamus, pig, ox, and deer, from the Sevâlik Mountains, at the southern base of the Himalayas, between the Sutluj and the Ramgunga rivers.	Capt. Proby Cautley, F.G.S.
		Specimens from the Lipari Isles, Etna, &c.	Hon. John Stewart Wortley, F.G.S.
		Fossils from Hordwell Cliff.	Charles Stokes, Esq., F.G.S.
		Head of *Ichthyosaurus communis*.	Marquis of Northampton, F.G.S.
		Selenite from Prince Regent's Inlet, lat. 73° 27′ 23″, long. 10° 50′ 34″.	Capt. Sir Edw. Parry, R.N., F.G.S.
	15.	Fossils from the green-sand and the transition limestone of Devonshire.	R.A.C. Austen, Esq., F.G.S.
Apr.	18.	Specimens from the coal-measures and the Silurian system of Coalbrook Dale.	Joseph Prestwich, jun., Esq., F.G.S.
	25.	Specimens from the lias at Lyme Regis.	Visct. Cole, M.P., F.G.S.
		Specimens from the marlstone near Lyme Regis.	Viscount Cole, M.P., F.G.S. and Sir Philip Grey Egerton, Bart., M.P., V.P.G.S.
May	1.	Coal shale, with *Goniatites Listeri*, from the Bradford coal-field.	Visct. Oxmantown, F.G.S.
		Specimens from the London clay, near Chalk Farm.	N. T. Wetherell, Esq., F.G.S.
		Specimen of *Anadonta Parishii*.	Woodbine Parish, Esq., Sec. G.S.

1836.	SPECIMENS.	DONORS.
May 22.	*Scaphites Hillsii*, from the lower green-sand, Maidstone.	Marquis of Northampton, F.G.S.
23.	Remains of the elephant, &c. from Bollingdon Hill, Essex.	Elliston Allen, Esq.
	Specimens from the crag.	Edw. Charlesworth, Esq., F.G.S.
June .	Specimens from the chalk at Buxton, Norwich.	John Wright, Esq.
	Specimens of fossil wood from Egypt.	Lord Prudhoe.
July 30.	Additional remains of the mastodon, mammoth, &c., from the Sevâlik Mountains.	Captain Cautley, F.G.S.
*Aug.*23. *Sep.* 13.	Specimens from Balmen, Badra and Linput, in Cutch, from Sinde and the banks of the Indus.	Lieut. Burnes, H. E. I. C. Service.
27.	Specimens from the northern side of Kunour, lat. 32° 30′, long. 78°, in the Himalayas.	Lieut. Vicary.
	Specimens from the chalk of Gogmagog Hill, near Cambridge.	N. B. Dennys, Esq.
	Specimens from the chalk of various parts of England.	Henry Gregory, Esq.
	Fossils from the chalk near Hemel Hempstead.	H. C. White, Esq., F.G.S.
	Fossils from the limestone of Teignmouth.	J. K. Harvey, Esq., F.G.S.
Nov. 16.	Specimen of a fossil crustaceous animal, from the coal formation near Glasgow.	John Scouler, M.D., F.L.S., &c.
	Specimens of fossil wood found in rounded boulders of cornbrash at the summit of the Blisworth Ridge, Northamptonshire.	Richard Creed, Esq.
17.	Specimens of coal plants from Cape Breton.	— Brown, Esq.
Dec. 3.	A collection of specimens from Guiana, collected by Robert Schomburgk, Esq.	The Royal Geographical Society, and Robert Schomburgk, Esq.
6.	Specimens of fossil wood from Van Diemen's Land.	— Williamson, Esq.
14.	Fossils from Barbadoes; casts of shells from Australia; and a specimen of new red sandstone found in the fen-land of Lancashire, at the depth of 512 feet.	G. B. Greenough, Esq., V.P.G.S.
	Specimens from the new red sandstone and conglomerate at Allesley, Warwickshire.	James Yates, Esq., F.G.S.
	Specimens of granite from Penrhyn, Cornwall.	Geo. Rennie, Esq., F.G.S.
	Specimen of ammonites in flint, from Box Hill near Dorking.	.....
	Specimens of a fossil tree at Allesley, Warwickshire, and of the new red sandstone in which it was found.	Rev. Prof. Buckland, D.D., F.G.S., and Jas. Yates, Esq., F.G.S.
	Boulders from the sea-shore at Barcelona.	W. P. Hunter, Esq., F.G.S.
	Shelly limestone from the old Roman quarries near Tarragona.	.....
1837.		
Jan. 1.	A specimen of iron pyrites from the peat associated with the warm springs of Egra.	A. B. Granville, M.D., F.G.S.

1837.		SPECIMENS.	DONORS.
Jan.	1.	Specimens from the freshwater deposit at Grays; specimens from the plastic clay at Woolwich and Upnor; and a specimen of fossil wood from Bayswater.	John Morris, Esq.
Feb.	1.	Specimens from Cutch.	Lieut. Col. Sykes, F.G.S.
Feb.		Polished agates.	G. B. Greenough, Esq., F.G.S.
		Specimens from Barbadoes.	Joseph Cowhurst, Esq.
		Casts of fossils from France.	M. Puzos.
	23.	Specimens from the chalk of Norfolk, and recent shells.	C. B. Rose, Esq.
		Specimens from Cornwall.	James Yates, Esq., F.G.S.
		Specimens from Finland and Norway.	Fras. Walker, Esq., F.G.S.
		Specimens from Sarn Badrig, Cardigan Bay.	Lieut. Sheringham, R.N.
		A collection of British and foreign specimens.	Miss Lousada.
Mar.	.	Specimens of stalagmite from Gibraltar.	L. H. Petit, Esq., F.G.S.
	21.	Specimens from the crag of Suffolk.	John Brown, Esq., F.G.S.
April	5.	*Pentacrinites Briareus*, from the lias, Lyme Regis.	Visct. Cole, M.P., F.G.S., and Sir Philip Egerton, Bart., M.P., F.G.S.
		Fossils from the mountain limestone of Ireland.	Visct. Cole, M.P., F.G.S.
		Specimens from Grignon, Hauteville and Bordeaux, in France, and Piacenza, in Italy.	Chas. Stokes, Esq., F.G.S.
		Polished specimens of the limestone of Kilkenny, and a boulder of the Hertfordshire pudding-stone; and granite from Newry, on the road to Belfast.	W. P. Hunter, Esq., F.G.S.
	19.	Hippurite from Perigord.	S. P. Pratt, Esq., F.G.S.
		Specimens from the coal-measures of Burdie House, and limestone from Glen Tilt.	W. P. Hunter, Esq., F.G.S.
May	1.	Specimens of granite, and of garnets in mica-slate, from between Dunkeld and Blair.	.....
		Polished specimens of fossil wood from Antigua.	Maj. Gen. Sir Pat. Ross, G.C.M.G., K.C.H.
	2.	Osseous breccia from Cerigo.	W. F. Forbes, M.D.
	3.	Specimens of coal plants from Rotherham.	— Roberton, Esq.
	17.	Specimens from Faxoe.	Dr. Forchhammer, For. Mem. G.S.
		A suite of geological specimens from New Jersey.	Prof. H. D. Rogers, F.G.S.
	31.	Tooth of a mastodon from the crag of Norfolk.	Rev. John Gunn.
June	1.	Recent corals from Bermudas.	L. S. Coxe, Esq., F.G.S.
	15.	*Ammonites Lewesiensis*, from Shakspeare's Cliff, Dover.	F. Bonney, Esq.
	23.	Specimens of coal shale with vegetable impressions, from the coal-measures at Rhymney, near Merthyr Tydvyl.	Thomas Williams, Esq.
		Fossils from the mountain limestone in the Isle of Man.	Capt. Bentham.
	24.	A collection of fossils and rocks from Cutch.	Capt. Grant, F.G.S.
July	6.	Specimens from Sicily, Vesuvius, and from the neighbourhood of Naples.	John Auldjo, Esq., F.G.S.

1837.		SPECIMENS.	DONORS.
July	25.	Fossils and specimens of rocks from the eastern portion of the great basaltic district of India.	J. G. Malcolmson, Esq., F.G.S.
	26.	Specimens from the country between Madras and Neilgherries, and from other parts of India.	Dr. Benza.
Aug.	3.	Specimens from Cape Horn, the Straits of Magellan, &c.	Charles Collett, Esq., R.N., by Capt. Beaufort, R.N., Hon. Mem. G.S.
		Specimens from the pitch lake at Trinidad.	Gilpin Gorst, Esq., F.G.S.
	9.	Specimens of iron ore from Cornwall.	Benj. Tucker, Esq., F.G.S.
	24.	A polished slab of the fossil tree at Cragleith.	Messrs. Walker & Burgess.
	26.	Specimens from the Gold Coast.	Capt. Vidal, R.N., by Capt. Beaufort, R.N., Hon. Mem. G.S.
	30.	A stag's horn from the Preston and Wyre railway, Lancashire.	Decimus Burton, Esq., F.G.S.
		Specimens of the Whitby and Whitehouse building-stone, and of the Whitby porcelain earth, in contact with a whinstone dyke.	Whitby Stone Company.
Sept.	8.	Casts of Basilosaurus, the Saurian of Missouri.	R. Harlan, M.D.
Oct.	4.	Specimens from the Dead Sea.	Henry Beek, Esq.
	21.	Specimens from near the trap dyke, Penrhyn slate-quarries, Bangor.	Mr. John Morris.
		A collection of specimens from Australia.	Major T. L. Mitchell, F.G.S.
		Specimen of Ficoides.	Mrs. Maj.-Gen. Le Coutier.
		Fossil from the mountain limestone, the oolitic and cretaceous systems of England.	Miss Benett, of Norton House.
		A stone brought up with the lead, in 80 fathoms water, upon the edge of the bank about 50 miles east from Cape St. John, Slater Island.	Capt. Beaufort, R.N., Hon. Mem. G.S.
		Specimens from Madras, Beder, &c.	Robert Cole, M.D.
1838.			
Jan.	3.	Specimens from Madeira.	Wm. Christie, jun., Esq.
	17.	Vertebra of a Plesiosaurus from Terry's Pits, Hasely Mill, Oxfordshire; with a fragment of a stag's horn from the same locality.	Rev. T. Birkett.
	31.	Specimens from the slate of Devonshire.	Henry MacLauchlan, Esq., F.G.S.
Feb.	1.	Specimen of the asphaltic mastic.	T. W. Simms, Esq.
		Specimens from Bognor.	James Laird, M.D., F.G.S.
Mar.	21.	A mass of *Ostrea gregarea* from near Oxford.	Rev. Prof. Buckland, D.D., V.P.G.S.
		Specimens of copper ore and malleable iron from Southern Africa.	Capt. Alexander.

1838.		SPECIMENS.	DONORS.
Mar.	21.	Stratigraphical model of the Under Cliff, Isle of Wight.	L. L. Ibbetson, Esq., F.G.S.
April	8.	Rock specimens from the Seychelles Islands.	J. Harrison, Esq.
	25.	Fossils from the Himalayas.	Sir T. D. Acland, Bart., F.G.S.
		Specimens from Upper Assam.	John MacClelland, Esq.
May	1.	Cast of *Hamites articulatus*, from the oolitic formation, Normandy.	Marquis of Northampton, F.G.S.
	8.	Specimens from the North Lancashire coal-field.	Charles Dawes, Esq.
	9.	Cast of the head of the *Mastodon longirostris*, from Epplesheim.	Sir P. G. Egerton, Bart., M.P., F.G.S.
		Specimens from Boulogne and Guernsey.	Robert Cole, Esq., F.G.S.
		Specimen of Plagiostoma from the Gulf of California.	— Hodges, Esq.
	23.	A specimen of *Dapedium orbis* (Agassiz), from Barrow-upon-Soar.	Rev. John Pye Smith, D.D., F.G.S.
June	1.	Specimens from Central France.	G. P. Scrope, Esq., M.P., F.G.S.
		Specimens of obsidian, manganese containing silver and native quicksilver, from Mexico.	John Taylor, Esq., Treas. G.S.
		Remains of fossil fishes from Goldworth Hill, near Guildford.	Allan Sibthorpe, Esq.
		Fossils from Bognor.	James Laird, M.D.
		Trilobites, corals, and rock specimens from Hudson's Bay.	The Earl of Selkirk.
		Specimens from St. Helena.	R. F. Seale, Esq., F.G.S.
		Fossils from the chalk of Berkshire.	R. Grantham, Esq., F.G.S.
		Shells from the crag of Felixstow.	Rev. Belford Dennys.
		Geological specimens from Columbia River and other parts of North America.	Earl of Selkirk.
		Specimens from Gibraltar, and minerals from Cornwall.	Capt. Beaufort, R.N., F.G.S.
		Fossil infusoria and artificial and natural silica from recent infusoria, and glass, manufactured from living infusoria.	Prof. Ehrenberg.
		The collection of minerals, fossils, and geological specimens belonging to the late Nathaniel John Winch, Esq., Hon. Mem. G.S.	Bequeathed by the late N. J. Winch, Esq., Hon. Mem. G.S.
		Fossils from the lower green-sand.	Dr. Mantell, F.G.S.
		Belemnites from Mount Joli.	John Vincent, Esq.
		Fossils of the mountain limestone from Kirby Lonsdale and Clitheroe.	Rev. J. W. Fisher, F.G.S.
		Specimens of fish-scales in flint.	Dr. Reade.
		Specimens from Underbarrow, near Kendal.	Gilpin Gorst, Esq., F.G.S.
Nov.	17.	Cast of bones of reptiles discovered by Dr. Mantell in Tilgate Forest.	Dr. Mantell, F.G.S.
		Fossil Pinnas from Honey Pen Hill, near Bristol.	G. Cumberland, jun. Esq.

1838.		SPECIMENS.	DONORS.
Nov.	17.	New red sandstone from Birkswell, Warwickshire.	R. I. Murchison, Esq., V.P.G.S.
		Cast of the jaw of a Chœropotamus.	Rev. W. D. Fox.
		Fossil turtle, from Harwich.	S. R. Heseltine, Esq.
		Gryphæa sinuata, from the lower green-sand.	Mr. Binsted.
		Casts of *Calymene Blumenbachi*, *Asaphus caudatus*, and *Encrinites moniliformis*.	Mr. Deck, F.G.S.
		Specimens from Christiana.	Rev. W. Bilton, F.G.S.
		Specimens from Western Africa, between Sierra Leone and Fernando Po, collected by Capt. Vidal, R.N.	Capt. Beaufort, R.N., Hon. Mem. G.S.
Dec.	20.	An Index Geological Map of the British Isles, by John Phillips, Esq., F.G.S.	J. W. Lowry Esq.
1839.			
Jan.	9.	Specimens from the Island of Ascension, collected by Lieut. Bedford, R.N.	.....
		Specimens of chalcedonic flints from Wiltshire.	Rev. Charles Watkins.
	23.	Specimens from Lisbon.	W. Edward Logan, Esq., F.G.S.
	27.	Specimens from Southern Africa and the Cape de Verde Islands.	Lieut. Nelson, R.E.
		Specimen of limestone from Bermuda, inclosing a *Cyprea vitellus*.	Lieut. Symonds, R.E.
Feb.	26.	Bones from the crag of Easton and Bulchamp Pit, Suffolk.	Capt. Alexander, F.G.S.
		Corals from the mountain limestone of Lough Erne.	Viscount Cole, M.P., F.G.S.
Mar.	13.	A specimen of polished agate from Constantinople.	Edw. Clark, Esq., F.G.S.
		Plants from the Pembrokeshire coal-field.	Henry Still, Esq., F.G.S.
		Minerals from Nova Scotia.	Abraham Gesner, Esq.
	27.	Casts of Echini and shells.	Professor Agassiz.
		Fossils from the lias near Cheltenham.	R. B. Grantham, Esq., F.G.S.
		A polished specimen of *Spongus labyrinthus* in flint, from Sussex.	Marquis of Northampton, F.G.S.
		Section of an Alcyonite in flint.	Rev. Charles Watkins.
Apr.	10.	A collection of fossil shells from the Apennines.	Sig. Michellotti.
	15.	Impression in tin-foil of *Nereites Cambrensis*.	Rev. J. B. Reade.
		Shells from the recent deposit on the banks of the St. Lawrence.	Cha. Lyell, Esq., V.P.G.S.
		Fossils from the Ludlow formation near Ludlow.	Rev. W. R. Evans.
		Shells from the Pampas of Buenos Ayres.	Sir Woodbine Parish, K.C.H., F.G.S.
		Fossils from the London clay.	N. T. Wetherell, Esq., F.G.S.
May	22.	A slab of new red sandstone from Eaton, Cheshire, with ripple marks and impressions of Cheirotherium footsteps.	Sir Philip Egerton, Bart., M.P., F.G.S.

1839.		
May 22.	A collection of fossils from the south of Ireland.	R. Griffith, Esq., F.G.S.
	Slab with impressions of plants from Philadelphia, and fossils from Cornwall.	Dr. Mantell, F.G.S.
June 5.	Fishes from the old red sandstone of the counties of Murray, Nairn, Inverness, and Banff.	J. G. Malcolmson, Esq., Rev. G. Gordon, and William Staples, Esq.
	Casts of *Ammonites Henslowi.*	Mr. Deck, F.G.S.

IV. *Miscellaneous.*

1835.	MISCELLANEOUS.	DONORS.
June 23.	A specimen basket.	Capt. Chapman, Roy. Art.
1836.		
Apr. 19.	Bust of the late Professor Playfair.	Leonard Horner, Esq., F.G.S.
	Two specimens of an artificial substance resembling shell.	.....
1837.		
Mar. 21.	Geological model of the Isle of Wight.	J. W. Lowry, Esq.
May 9.	Geological intersector by Prof. John Phillips, F.G.S.	Prof. J. Phillips.
17.	Cinder from a burnt hay stack.	Sir W. Parish, K.C.H., F.G.S.
June 1.	Roman coin-mould found at Lingwell Gate, near Wakefield, containing infusoria.	Rev. J. B. Reade.
	Bust of Dr. William Smith.	W. P. Hunter, Esq., F.G.S.
	Model of Clare Island, on the Coast of Mayo, Ireland.	William Bald, Esq., F.G.S.
	Two Denarii of Geta and Antoninus Pius.	Mr. W. Tilt.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

Fig. 6, 7 and 8. Vertebræ, natural size: p. 352.

Fig. 9. Chevron bone, natural size: p. 353.

Fig. 10. Rib, natural size: p. 353.

Fig. 11. Fragment of a coracoid: p. 354.

Fig. A. represents part of the dental bone of *Saurodon lanciformis*, magnified three times: fig. B. portion of the upper jaw and detached teeth of *Saurodon Leanus*. They are both taken from the plate which illustrates Dr. Hay's Memoir on the Saurodon. Amer. Phil. Trans., New Series, Vol. iii. p. 471. Pl. XVI.

Plate XXX.: p. 354.

Fig. 1 to 6 reduced to one-half, *Fig.* 7 to 12, natural size.

Fig. 1, 1*a*. Humerus: p. 354. *Fig.* 2. Radius: p. 354.

Fig. 3, 4, 4*a*. Femurs: p. 355. *Fig.* 5. An Ischium: p. 355.

Fig. 6. A Tibia: p. 356. *Fig.* 7, 7*a*. A Fibula: p. 356.

Fig. 8 to 13. Metacarpal or Metatarsal bones and uncial Phalanges: p. 356.

PLATE XXXI.

Illustrates the Rev. W. B. Clarke's paper on the Geological Structure and Phænomena of the county of Suffolk, &c.: p. 359.

WOOD-CUTS

To illustrate Mr. Strickland's paper on the Geology of the Thracian Bosphorus: p. 385.

Section from Constantinople to Symplegades: p. 385.

Section of a conglomerate near Filbornou, consisting of angular fragments of trachyte, imbedded in a tufaceous paste and traversed by veins of calcedony: p. 389.

Section on the north side of Anadoli-fanar: p. 392.

PLATE XXXII.

Map and Sections to illustrate Mr. Strickland's Memoir on the Geology of the neighbourhood of Smyrna: p. 390.

PLATE XXXIII.

Map and Sections illustrative of Mr. Strickland's paper on the Geology of Zante: p. 403.

PLATE XXXIV.

To illustrate Mr. James de Carle Sowerby's paper on *Crioceratites Bowerbankii* and *Scaphites gigas*: p. 409.

Fig. 1. *Crioceratites Bowerbankii*: p. 410.

Fig. 2. *Scaphites gigas*: p. 411.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

PLATES XXXV. to XLI.

Illustrate Mr. Prestwich's Memoir on Coalbrook Dale: p. 413.

Plate XXXV.

Map on the scale of one inch to a mile, the topography being copied from the Ordnance Map.

Plate XXXVI.

Sections, horizontal scale 2 inches to a mile.

Fig. 1. Longitudinal section from the Wharf, near Lilleshall Hill, at the northern extremity of the coal-field, to Shirlot Hill.

Fig. 2. Transverse section through Lilleshall Hill.

Fig. 3. West and east section through Donnington Field.

Fig. 4. Transverse section from a little south of Hadley to Woodhouse Hill.

Fig. 5. West and east section from Buckatree Hall to the Great East Fault.

Fig. 6. West and east section from Wrekin Farm to Randley.

Fig. 7. West and east section from a little west of Primrose Hill to Brans Farm.

Fig. 8. West and east section from the Devil's Dingle to near Homer Farm.

Fig. 9. Transverse section from a little south of Coalbrook Dale to Sutton Hill.

Fig. 10. Transverse section from a little west of Benthall Edge to a little south of Sutton Maddock.

Fig. 11. West and east section from Wenlock Edge to Old Park.

Fig. 12. West and east section from Westwood Common to Apley Park.

Fig. 13. Diagonal section from N.N.W. to S.S.E., or from Cluddley to Dunvall.

Fig. 14. North and south section from near Hadley to a little south of Willey.

Fig. 15. N.N.W. and S.S.E. section through the Wrekin to the Severn.

Fig. 16. West and east section from Henley Farm to Pendlestone Rock.

Plate XXXVII.

Diagram illustrative of the principal coal-shafts in their range from north to south, of the changes in the mineral composition, thickness and number of the beds; also of the nature and distribution of the organic remains. The vertical scale is to the horizontal in the proportion of about 26 to 1, in order to represent every bed.

Plate XXXVIII.

Fossil Plants from the coal measures described by Mr. John Morris and engraved by Mr. James de Carle Sowerby.

Fig. 1. *Halonia disticha, n. s.*

Length of specimen 4 feet; width from 4 to 6 inches.
Stems and leaves unknown.

Stem? internal structure unknown, replaced by sandstone.

External structure; stem flattened, sinuous, with bifarious ascending protuberances, somewhat conical and obliquely truncated, the apex of each forming a nearly circular scar, with a depressed lateral cavity; the side of each scar marked by a transverse depression; surface of the stem thickly covered with small oblong or irregular shaped projecting cicatrices, disposed in a quincunxial order, which become elongated and larger as they approach the protuberances.

In the older portions the cicatrices are less prominent.

The resemblance of this specimen in some characters to Halonia has induced us to place it in that genus; although it differs in the smaller number of protuberances which are found on the surface, the bifarious position of which will at once distinguish it from all the other species.

Fig. 2. Bechera charæformis, (Sternberg, t. 55, f. 3, 5.) *B. delicatula*? Sternb. t. 49. f. 2. Stem striated, jointed, verticillately branched, *branches* dichotomously whorled, leaves subulate.

This specimen is the same as Sternberg's figure, t. 55, and his *B. delicatula* appears to be only an imperfect variety of the same species.

Fig. 3. Stigmaria ficoides. The portion of stem of which the figure is a transverse section, is in more perfect preservation than the specimens of *Stigmaria* usually are found; it is of a nearly cylindrical form, about $4\frac{1}{2}$ inches diameter, the external surface exhibiting the usual markings of this curious plant; the internal part, with the exception of a vascular cylinder (also mineralized), being replaced by clay ironstone.

In the Fossil Flora, t. 31—36, are figures and descriptions of *Stigmaria ficoides*, and at t. 156 is shown the structure of the same; and although we cannot add much new information to that previously given by Prof. Lindley, it has been thought advisable to have another section represented with a view of showing what has hitherto not been well illustrated in the published figures of its structure. The internal cylinder in the specimen (fig. 3.) is eccentric, and consists of wedge-like portions of vascular tissue, the rounded origin of which, internally, is well-defined; these wedges are generally of equal or nearly equal size, but they occasionally become confluent by the joining of two or more of them together. The form of the space necessarily left, or interstices between the sections where these are distinct, varies a little, in some cases being of nearly equal breadth throughout, and in others becoming narrower outwards and appearing to terminate or contract about the middle of the vascular tissue, beyond which they again frequently widen outwards: these spaces often contain portions of oblique and smaller vascular cords, apparently arising at different depths in the vertical cylinder; the origin and connexion of which with the cylinder is shown in the oblique section, where a single series of vessels is seen passing from it surrounded by tissue of smaller diameter. Pl. XXXVIII. fig. 3 *a*.

In no specimen yet examined has the course of the oblique cords been absolutely ascertained, but there can scarcely be any doubt, as suggested by Mr. Brown (to whom we are also indebted for the above observations,) that these vessels after

arising from the cylinder passed to the tubercles of the surface, through the thick cellular tissue which once probably occupied the larger space in the original plant. The discovery of these smaller oblique vessels is an interesting feature in the anatomy of *Stigmaria*; and they have also been pointed out by Mr. Brown as existing in *Anabathra*, and one of these is actually figured by Mr. Witham in his work[1], but considered by him (p. 41.) as a section of a medullary ray. The analogous vessels existing in *Lepidodendron Harcourtii*, as figured by Mr. Witham[2], appear to arise from the outer part of the vascular cylinder. A somewhat similar arrangement is also found in that division of *Lycopodiaceæ*, consisting of *Psilotum* and *Tmesipteris*: in those genera, the vascular cylinder, from which the oblique cords proceed, includes a central pith[3].

Fig. 3 *b*. Shows that the vessels are much smaller at the internal rounded portions of the wedges.

Fig. 3 *c*. Exhibits the oblique cords, consisting of smaller vessels surrounding vessels of larger diameter nearly equal to those forming the vertical tissue.

Fig. 3 *a*. Is an oblique section which exhibits the connexion of these vascular cords with the vertical tissue.

Stigmaria melocactoides, Sternberg, Flor. der Vorw. p. 38.

Stem deformed, 6 to 8 inches thick, with the apex rounded, pertuse, and filled with sandstone; leaves unknown, cicatrices like *S. ficoides*. This I believe may prove to be a terminal portion of *S. ficoides*.

Sternberg considers *Phytolithus verrucosus* of Steinhauer, Martin, and Parkinson as a synonym of this species; but it rather appears to be only a terminal portion of *S. ficoides*.

Fig. 4. *Carpolites Zamioides, n.s.* The figure is somewhat similar to the *Bothrodendron punctatum*, Fossil Flora, t. 218, and which is considered to have been a cone; an opinion that can scarcely be entertained of our specimen; the ovate and compressed form of which is more analogous to the seed of some species of Zamia or even Palms.

Fig. 12. *Carpolites Helicteroides, n.s.* Fruit ovato-lanceolate, attenuate at both ends; polycarpous?, Carpella 4 or 5, twisted spirally but not closely together.

The apparent resemblance of this specimen to the cast of a fruit of Helicteres has suggested the specific name, although its affinity to that genus may be very doubtful.

The above name was given to the specimen figured previously to our having seen a somewhat similar fossil described by Presl in the last part of Sternberg's Flora der Vorwelt, where it is placed under the genus *Palæoxyris* of Brongniart, from its supposed resemblance to the inflorescence of the recent *Xyris*, an opinion scarcely borne out by the general appearance of this fossil; it has therefore been retained under *Carpolites* for the reason stated above. The two species already

[1] On the Internal Structure of Fossil Vegetables, 2nd Edit. t. 8, f. 12.

[2] Trans. of the Nat. Hist. Soc. of Newcastle, 1832.

[3] Ad. Brongniart, Hist. des Végét. Foss. v. ii. p. 44, 45.

figured of this remarkable form have been obtained from the new red sandstone of Bamberg.

Fig. 5. *Antholites anomalus, n.s.* Flower spiked, more crowded towards the apex, calyx apparently shorter than the petals?, furnished with a small lanceolate bract; stigma or Carpella? bilocular, elevated upon a long curved filament.

The absence of more defined characters renders the affinity of this plant doubtful. It has some resemblance to the flowers of *Orobanche* or even *Scitamineæ* as *Hedychium*, which have, however, large fleshy bracts. In the *Bromeliaceæ* are flowers of a somewhat similar shape, but they are not furnished with the long filamentous appendage which appears to be characteristic of this fossil. The genus *Lacis* has a two-celled Carpella upon a long pedicle, but the flowers are rather different from our specimen.

Cyclopteris semiflabelliformis, n.s. Pl. XXXVIII. fig. 7. Frond pinnate?, leaves entire, *half-fanshaped*; veins distant, diverging, dichotomously furcate.

This specimen has some affinity to the leaf of *Salisburia adiantifolia*, but differs from it in the veins being more numerous and more generally furcate along the upper margin, which is entire and not deeply cleft as in Salisburia. It more closely resembles the lower leaves of *Otopteris acuminata*, var. *brevifolia*, Foss. Flor. t. 208.

Lycopodites? longibracteatus, n.s. Pl. XXXVIII. fig. 8, 9, 10, 11. Stem round, marked by the cicatrices of the fallen leaves, which are close, lozenge-shaped, and spirally disposed.

Fructification in terminal imbricated spikes, thecæ reniform, minutely tuberculated, each attached by its centre to the base of a *long, lanceolate, foliaceous bractea*.

The thecæ resemble in shape those of the recent genus *Stachygynandrum*, but as the capsules vary in form in different parts of the spike in that genus, it is difficult to assign its affinity to that division of the *Lycopodiaceæ*.

The capsules, Pl. XXXVIII. fig. 8, 8 *a*. of this species, neither bituminized nor mineralized, but in a state of brown vegetable matter, are very abundant in some of the coarser sandstones of the coal-measures.

Plates XXXIX. and XL.

Fossil shells from the coal-measures described and engraved by Mr. James de Carle Sowerby, F.L.S.

Fig. 1. *Donax? sulcata.* Subtriangular, convex; anterior side rounded; posterior side produced, pointed; beaks prominent; in the cast there is a furrow descending obliquely from each beak towards the posterior angle. Length in some specimens 1 inch 4 lines; width $1\frac{3}{4}$ inch.

The name of this fossil is but temporary, neither the structure of the hinge nor the external surface being known.

Fig. 2. *Venus? carbonaria.* Obovate, convex; anterior side rounded; the posterior side truncated, squarish; beaks rather prominent; shell most gibbose towards the beaks.

Length 1 inch 4 lines, width $1\frac{1}{2}$ inch.

These casts have much the aspect of Mactræ; the hinge is unknown.

Fig. 3. *Nucula æqualis.* Transversely elongated, convex, marked with concentric ridges; anterior side rounded; posterior separated by a ridge and truncated; beaks nearest the anterior side.

Width twice the length, which is a quarter of an inch; 3 *a.* is 3 *b.* magnified twice.

Fig. 4. *Nucula accipiens.* Transversely oval, convex, concentrically striated; beaks nearest the anterior side.

Length $3\frac{1}{2}$ lines, width above 4 lines.

Fig. 5. *Nucula acuta.* Transversely ovate, convex, concentrically striated, anterior extremity rounded, posterior extremity produced, pointed.

Length $1\frac{1}{2}$ line, width $2\frac{1}{2}$ lines; 5 *a.* is 5 *b.* magnified twice.

An elegant small shell.

Fig. 6. *Unio Urii,* (Fleming's British Animals, 417. Ure's History of Rutherglen and Kilbride, 311. t. 16. f. 4.). Transversely much elongated, very convex, wavy; posterior extremity rather pointed; beaks near the small anterior side.

The general form approaches to cylindrical. Width $2\frac{1}{2}$ times the length, which is about $1\frac{1}{3}$ inch.

Fleming has confounded this with *Unio ovalis* of Martin (*Petrif. Derb.* t. xxvii. f. 1, 2.) which is quite distinct.

Fig. 7. *Unio Ansticei.* Very convex, wavy, curved, anterior side longest, forming a lobe; posterior side obtuse, gaping? Surface concave towards the front; beaks near the anterior extremity. 7 *a.* Reduced figure to show the front of the shell.

Length $1\frac{1}{2}$ inch, width $2\frac{1}{2}$ inches.

This has much the form of a *Mya.*

Fig. 8. *Unio parallelus.* Transversely elongated, rather flattened, wavy; sides almost equally rounded; front and back straight, parallel; beaks near the anterior extremity. 8 *a.* Shows the depth of the valves.

Length 1 inch 4 lines, width $2\frac{1}{4}$ inches.

Fig. 9. *Unio dolabratus.* Subquadrate, wider than long, rather flat with an oblique convexity along the middle, even; anterior side small, rounded; the posterior side flattened and truncated; beaks near the anterior side.

Length 13 lines, width about $1\frac{3}{4}$ inch.

Fig. 10. *Unio modiolaris.* Transversely elongated, convex, even, with an oblique obtuse keel along the middle; anterior side small, rounded; the posterior truncated, flattened; beaks near the anterior side.

Length $\frac{3}{4}$ inch, width about twice as much.

Fig. 11. *Unio Phaseolus.* Transversely much elongated, three times as wide as long, even, convex; anterior side very small, pointed; the posterior flattened, rounded.

Length 3 lines, width 7 lines.

Fig. 12. *Unio aquilinus.* Transversely ovate, curved, flattened, rugged; posterior side pointed; beaks near the rounded anterior side.

Length half the width, which is 14 lines.

Fig. 13. *Unio centralis.* Transversely oval, rather convex; beaks nearly central.
Length 11 lines, width 17 lines.

Fig. 14. *Unio robustus.* Obovate, convex, strongly marked with lines of growth, nearly as long as wide; posterior extremity rather pointed.
Length 1 inch 5 lines, width nearly $1\frac{3}{4}$ inch.

Fig. 15. *Modiola carinata.* Obliquely elongated; valves boat-shaped, deep; anterior lobe small.
Length 11 lines, width more than $\frac{1}{2}$ an inch.

Fig. 16. *Mytilus triangularis.* Triangular, with a rounded front, rather flattened, keeled towards the beaks.
Length 11 lines, width about $9\frac{1}{2}$ lines.

Fig. 17. *Avicula quadrata.* Quadrangular, convex, keeled; anterior lobe small, pointed; front rounded.
Length about an inch, width nearly the same.

Fig. 18. *Avicula modiolaris.* Obliquely elongated, compressed; keeled towards the beaks; anterior lobe pointed.
Length 8 lines, width $4\frac{1}{2}$ lines.

Fig. 19. *Pecten gentilis.* Oblong, convex, smooth, with 15 slightly-elevated rays, which are alternately long and short; ears middle-sized, equal.
Length 5 lines, width 5 lines.
A small neat shell.

Fig. 20. *Pecten scalaris.* Oblong, convex, concentrically striated, radiated, radii about 15, acute.
Length 6 lines, width 5 lines.

Fig. 21. *Spirifera bisulcata,* (M. C. t. 494.) This specimen shows the impressions of the internal spiral appendages, which, together with the long hinge-line, characterize the genus *Spirifera.*

Fig. 22. *Globulus vetustus.* Globose, smooth; spire pointed; umbilicus very small, open.
Height 11 lines, diameter 9 lines.

Fig. 23. *Littorina? obscura.* Oblong, umbilicated? smooth? spire elevated; whorls rather flattened on the sides.
Height 14 lines, diameter 10 lines.
The specimens are imperfect casts; they resemble the *L. littorea,* but are more elongated and have the whorls more distinct.

Fig. 24. *Turritella? clavata.* Turreted, conical, smooth; whorls about 8, flat.
Height 10 lines, diameter 5 lines.
This being only part of a cast, the genus cannot be ascertained with certainty.

Fig. 25. *Turritella? minima.* Turreted, conical, ribbed; ribs obtuse, about 16 to each whorl; whorls about 10.
Height 7 lines, diameter $2\frac{1}{2}$ lines.

Fig. 26. *Polyphemus? fusiformis.* Fusiform, smooth; aperture half the length of the shell, narrow; columella curved?
Height about $2\frac{1}{4}$ inches, diameter above an inch.

This is the internal cast of a shell of a very unusual form,—we have referred it to Montfort's genus *Polyphemus*, as bearing the nearest resemblance to it of any we know. The curvature is possibly the effect of fracture.

Plate XL.

Fig. 1. *Trochus*? *Usocona.* Conical, with a broad base, marked with obscure concentric ridges; whorls about 5, their upper parts convex, the lower concave, with a broad band in the hollow; edge of the base obtuse.

Height 2 inches, diameter nearly 3 inches.

The broad band around this shell would lead us to place it as a *Pleurotomaria*, did the lines of growth indicate that there ever was a deep sinus in the edge of the aperture.

Fig. 2. *Conularia quadrisulcata*, (M. C. t. 260. f. 3—6. *Silur. Syst.* p. 626. Pl. XII. f.)

Many of the specimens in ironstone have smooth furrows between the crenated ridges, as shown at fig. 2 *a.*, in others the furrows are crossed by striæ, as at fig. 2 *b.*, and both these forms may sometimes be found in one specimen, and arise from the presence or absence of a thin, dark brown skin or covering, the interior of which is smooth and the exterior wrinkled; the ridges are often denticulated or notched. See *ante*, p. 442.

Fig. 3. *Orthoceras scalpratum.* Lanceolate, compressed, smooth, slightly curved, with the edges angular, the inner one sharp; septa numerous; siphuncle small, near the obtuse edge.

Diameter $1\frac{1}{4}$ inch.

Fig. 4. Represents the interior of a small *Orthoceras* with numerous septa, and a nearly marginal siphuncle.

Fig. 5. 5 *a.* and 5 *b.* *Nautilus clitellarius.* Globose, umbilicated, septa numerous, much bent in the middle, truncated and not recurved at the ends; siphuncle central; umbilicus small, cylindrical; aperture above twice as wide as long.

The length of the aperture is $1\frac{1}{2}$ inch, the width $2\frac{3}{4}$ inches. Diameter of the shell $2\frac{3}{4}$ inches.

Fig. 5. A front view of a specimen in which only a few chambers have been filled with ironstone, and it may be remarked that most of the specimens are preserved in the same manner. The whole of the shell has decayed away, and with it all the inner whorls have disappeared: the ironstone not having entered them, that portion of the ironstone which filled the umbilicus wanting support has been subsequently broken and pressed into the cavity left by the shell. Fig. 5 *a.* is a lateral view of a similar specimen. Fig. 5 *b.* shows the remarkable curvature of the septa.

Fig. 6. *Nautilus concavus.* Subglobose, umbilicated, concave on the front; septa slightly arched; siphuncle central; umbilicus large; aperture nearly twice as wide as long.

Length of the aperture 7 lines, width 1 inch.

Diameter of the shell 1 inch 4 lines.

The simple curve of the septa and concave front distinguish this *Nautilus*.

Fig. 7. *Nautilus subsulcatus*, var. (*N. subsulcatus*, Phill. Geol. Yorks. ii. 233, in part.) This appears to be the same species as the limestone specimen figured by Prof. Phillips; but as it has a shorter aperture, we have thought best to distinguish it as a variety. That author refers to Coalbrook Dale as one of the localities of his species, so probably he had seen the shell before us.

Fig. 8. *Nautilus armatus*. Discoid, strongly ribbed, ribs elevated into tubercles; septa numerous.

Diameter of the shell about $2\frac{1}{2}$ inches.

There is only just enough preserved of this shell to show that the septa are entire, and that the ribs almost form spines; it much resembles *Ammonites armatus* of the Lias.

Fig. 9. *Nautilus falcatus*. Discoid, inner whorls exposed; the front convex; sides nearly flat; the outer edge of each whorl obtusely angular, the inner edge inclined towards the preceding whorl, the space between crossed by many arched ribs; septa simply concave; siphuncle central; aperture nearly square, but 6-sided, with two of the sides very small.

Length of the aperture 1 inch.

Diameter of the shell about $2\frac{5}{8}$ inches.

Fig. 10. *Bellerophon hiulcus*, var. (*B. hiulcus*, Fleming's British Animals, 338.) This differs from the specimens found in the mountain-limestone (M. C. t. 470. f. 1.), in having indistinct concentric striæ crossing those which are parallel to the lines of growth, and in all the striæ being sharper.

Fig. 11. *Bellerophon Navicula*. Globose, expanded, keeled, and flattened on each side of the keel, smooth; columella solid, produced; whorls rapidly increasing.

Diameter $5\frac{1}{2}$ lines.

The form of the aperture resembles the section of a boat, whence the name.

Plate XLI.

Remains of insects and fishes: p. 440.

Engraved by Mr. James de Carle Sowerby.

Fig. 1 *to* 4. *Limulus anthrax*. This fossil is considered by Dr. Milne Edwards to be a new species of *Limulus*.

Fig. 1 represents a nearly perfect specimen, with two of the legs extending from under the body: in figures 2 and 3 the shield is believed to have been separated; but Dr. Milne Edwards states that it is difficult to account for the three short horns exhibited by each specimen: figure 4 is a detached shield.

Fig. 5 to 7. *Limulus rotundatus*. This fossil is also considered by Dr. Milne Edwards to be a new species of *Limulus*.

Fig. 6 is the counterpart of figure 5. The membrane connecting the spines, and the circular outline of the animal, are considered to be peculiar.

Fig. 8. *Limulus trilobitoides*. (Buckland.)

Fig. 9. *Apus dubius*. The only living animal to which Dr. Milne Edwards could refer

this specimen is the *Apus corniformis*, of the rivers of central and southern Europe.

The remains represented in figures 1 to 7 are considered by Dr. Milne Edwards of great interest, as they exhibit characters intermediate between the living *Limulus* and the extinct Trilobite.

Fig. 10 and 11. Bones of the head of a *Megalichthys*. (See *antè*, p. 443.)

Fig. 12, a tooth, and fig. 13, a spine, are assigned provisionally to the genus *Hybodus*; the characters of the allied coal-measure genus *Diplodus* not being yet published by M. Agassiz.

Fig. 14. A tooth of a *Cochliodus*.

Fig. 15. A spine, assigned with doubts to the genus *Pleuracanthus*, the state of preservation of the specimen not being good. The spine is round but compressed, and is armed with two opposite rows of teeth. There are no traces in the specimen of the groove mentioned by M. Agassiz as one of the distinguishing characters of the genus.

WOOD-CUTS.

Fig. 1 to 4. Diagrams of the effects of faults in the coal-measures: p. 453.

Fig. 5. Diagram of the effects of lateral pressure produced by faults, from the Holywell pits, Malinslee: p. 454.

Fig. 6. Section of changes of level produced by dislocation in the "best coal" Meadow pits, Madeley: p. 454.

Fig. 7. Diagram of a step-like dislocation at Priorslee, due apparently to unequal hardness in the strata: p. 454.

Fig. 8 to 10. Diagrams of complicated dislocations: p. 454.

Fig. 11. Plan of minor faults and fractures inclosed between two principal faults, the Boundary and Ketley: p. 455.

Diagram of the minor faults which flank the Ketley fault near Donnington Wood furnaces: p. 456.

WOOD-CUTS

To illustrate the notice of Capt. Cautley and Dr. Falconer on the remains of a Fossil Monkey from the Sevâlik Hills: pp. 499–501.

Fig. 1 and 3. The Fossil Astragalus, natural size.

Fig. 2 and 4. Astragalus of the *Semnopithecus Entellus*, natural size.

WOOD-CUT

Explanatory of Mr. Darwin's paper on the Formation of Mould: pp. 505, 506.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

PLATE XLII.

Illustrates Mr. Owen's paper on the Dislocation of the Tail at a certain point, observable in the Skeleton of many *Ichthyosauri*: p. 511.

All the tails represented in the accompanying plate belong to skeletons of *Ichthyosauri* now in London and formerly in the collection of Mr. Hawkins: and these illustrations will not lose force from the fact of their being taken from figures of those skeletons published without any reference to the structure or hypothesis in question.

Upper right-hand figure from a specimen found in the lias at Walton in Somersetshire. (See Mr. Hawkins's work on *Ichthyosauri* and *Plesiosauri*: p. 32. Pl. XVII.)

Lower right-hand figure, from a specimen found in lias at Lyme Regis. (See Mr. Hawkins's work, p. 25. Pl. VII.)

Middle figure.
Left-hand upper figure. } See the Second Part of Mr. Hawkins's work.

Left-hand lower figure from a specimen found in lias at Walton in Somersetshire. (See Mr. Hawkins's work, p. 34. Pl. XXI.)

PLATES XLIII. to XLV.

Illustrate Mr. Owen's memoir on the Specimen of *Plesiosaurus Macrocephalus* (Conybeare) in the collection of Viscount Cole: p. 515.

Plate XLIII.

Reduced figure of Lord Cole's specimen, with comparative outline sketches of the paddles of *Plesiosaurus Dolichodeirus* and *P. Hawkinsii*: p. 515, *et seq.*

Plate XLIV.: p. 518.

Fig. 1. Diagram of vertebral elements: p. 518.
Fig. 2. Caudal vertebra of a Python: p. 518.
Fig. 3. Cervical vertebra of a Pelican: p. 518.
Fig. 4. Cervical vertebra of *Plesiosaurus Hawkinsii*, natural size: p. 523.
Fig. 5. Cervical vertebra of *Plesiosaurus arcuatus*, natural size.
Fig. 6. Section of terminal caudal vertebræ of *Plesiosaurus*: p. 528.

Plate XLV.: p. 531.

Head of *Plesiosaurus Hawkinsii* and of *Plesiosaurus Macrocephalus*.

PLATES XLVI. and XLVII.

Illustrate Mr. Malcolmson's memoir on the Eastern Portion of the Great Basaltic District of India: p. 537.

EXPLANATION OF THE PLATES AND WOOD-CUTS.

Plate XLVI.

Map and Sections.

The Map is intended only to assist the reader in following the description contained in the paper, and to exhibit a general view of the distribution of the rocks occurring between the Taptee and Pennar rivers. However imperfect this slight sketch confessedly is, it is hoped, that by embracing almost all the information yet obtained respecting this extensive region, it will correct the erroneous opinion entertained by many, of the simplicity of the geological structure of the South of India, and afford a nucleus around which additional and connected observations may be gradually arranged.

It has been found impossible to employ more than two colours for granite, gneiss and mica, chlorite and hornblende schists; for although many good observations have been made on the distribution of these rocks in certain parts of the country, yet the boundaries have not, in general, been clearly distinguished, nor is it always easy to do so. Where the stratified primary rocks prevail more abundantly than granite, a purple tint has been employed.

The Diamond sandstone and argillaceous limestone appear to constitute parts of one formation, and it has therefore been thought better not to distinguish them in a map of such small dimensions; though an attempt to do so has been made in the sections. The laterite is introduced only where it occurs resting on basalt, at Beeder in the Deccan; its limits are unknown. Near Nellone, a nearly similar formation rests on the primary rocks, and is probably formed from their decomposition *in situ*.

The trap is represented the same colour as in illustrations to Col. Sykes's Memoir on the Deccan, (Vol. iv. Pl. XXVI.) to enable the reader to connect the district represented in Col. Sykes's map with that contained in the accompanying map.

The section, fig. 1, at the top of the plate, extends from Bundlecund, beyond the north boundary of the map, to the Bangnapilly diamond-mines, situated between the 15th and 16th degrees of north latitude.

Section, fig. 2, extends across the Peninsula from the coast near Atchera (lat. about 16°) to Madras.

Plate XLVII.

Organic remains collected by Mr. Malcolmson, and described and engraved by Mr. James de Carle Sowerby: p. 550.

Fig. 1. *Chara Malcolmsonii.* Oblong, spheroidal, with 10 ribs; three of the ribs are produced at the apex. Natural size and magnified.

This capsule is composed of 5 tubes, each of which is curled twice round. The figures represent a cast of the interior, the tubes being split down, and the outer halves broken away and left in the chert. The specimens are silicified and constitute almost the entire mass of the rock, in which they occur associated with *Physæ* and *Paludinæ*.

Fig. 2. *Cypris cylindrica.* Twice as wide as long, almost cylindrical; front very slightly concave; the outer surface, which is very rarely obtained, is punctured.

Fig. 3. *Cypris subglobosa.* Subglobose, triangular, inflated; front concave.

The outer surface of this Crustacean is punctured as in *C. cylindrica.*

Both species occur abundantly in grey chert, with the *Unio Deccanensis* and other shells; and in various specimens of chert and indurated clay containing *Gyrogonites, Paludinæ, Physæ,* and *Limnei,* from the Sichel hills. The fossils are converted into calcedony.

Fig. 4 to 10. *Unio Deccanensis.* Transversely oblong, rather compressed; margin internally waved; shell very thick; surface finely striated. Fig. 6 is in limestone from the northern descent of the Sichel hills; the others are in chert from Munnoor. Natural size.

This species has often a ridge, which bounds the posterior portion, and is variable in size and elevation; it is most conspicuous in the limestone specimen, fig. 6, and in a cast in chert from Munnoor, fig. 7. Fig. 8 is possibly a very young individual, before the margin had assumed its wavy form. Fig. 9 is from a part of a group of many individuals of nearly one size, badly preserved in the same limestone as fig. 6; but as they are regularly oval, and do not show a waved margin, they may belong, as well as fig. 10, which is in grey chert from Munnoor, to a species distinct from *U. Deccanensis.* Some flattened specimens from this limestone are $2\frac{1}{2}$ inches broad.

Fig. 11 and 12. *Unio tumida.* Transversely obovate, smooth, gibbose; posterior extremity rather pointed; beaks near the anterior rounded extremity. Natural size.

The section of the two valves united is regularly heart-shaped. The shell is rather thin, and it has something of the contour of *Cyrena.* It occurs in the same limestone with fig. 6, and the substance of the shell is replaced by calcareous spar, which cannot be broken so as to show the hinge.

Fig. 13. *Limnea subulata.* Subulate, elongated, smooth; spine equal in length to the body; whorls five. In a nearly white, soft, siliceous stone, from Munnoor and Chicknee. Natural size.

Fig. 14, 15 and 16. *Physa Prinsepii**. Ovate, rather elongated, smooth, spire short; body-whorl largest upwards. Fig. 16, in a soft siliceous stone from Munnoor. Fig. 14 in chert from Munnoor, and fig. 15 in chert from Chicknee; the drawing represents the shell as wider than it is. Many of the specimens are crushed. The largest, fig. 15, are $2\frac{1}{2}$ inches long and upwards of an inch broad. Natural size.

Fig. 17 to 19. *Melania quadri-lineata.* Subulate, whorls about eight, with four striæ upon each; aperture nearly round. Fig. 17, in grey limestone from the same locality as 6 and 11. Fig. 18, in softish chert from Chicknee, associated with *Physa Prinsepii.* Fig. 19, in fine reddish grey chert, protruding from basalt near Munnoor, appears rather shorter in form than the others, but the spine is not perfectly exposed nor entire. Natural size.

* Mr. Sowerby has, with much propriety, named this fossil after Mr. James Prinsep, F.R.S., and Secretary to the Asiatic Society of Bengal; to whom Oriental science and literature are more indebted than to any other individual.—J. G. M.

Fig. 20 to 23. *Paludina Deccanensis.* Short, conical, pointed, rounded at the base; whorls 5 or 6, slightly convex, aperture round. Fig. 21 is in chert from Munnoor; and figs. 20 and 22 in indurated clay from between Munnoor and Hutnoor, the cavity of the shells being filled with calcedony. The young shell has a slight carina shown in fig. 20. Fig. 23 appears to be a crushed specimen; it is in laminated, indurated clay, Munnoor. This shell occurs, with *Physa Prinsepii*, in a beautiful green siliceous mineral at Munnoor; at Chicknee, and at the bottom of the Neermull pass. All the specimens natural size.

WOOD-CUTS.

Section of the Bangnapilly Diamond Mines: p. 541.

Section of the Lonar Lake and surrounding rocks: p. 562.

WOOD-CUT.

Map of part of Mazunderān to illustrate Dr. C. M. Bell's Geological Notes of a Journey from Tehran across the Elboorz Range to the Caspian, and back to Tehran along the course of the Heraz River: pp. 577, 581.

PLATE XLVIII.

Map and Sections to illustrate Mr. W. J. Hamilton's memoir on part of Asia Minor between the Salt Lake of Kodj-hissar and Cæsarea of Cappadocia. The map is constructed from original documents. The descriptions engraved on the plate explain sufficiently the range and nature of the Sections: p. 583 *et seq.*

WOOD-CUT

To illustrate Mr. Strickland's notice of some remarkable Dikes of Calcareous Grit, at Ethie, in Ross-shire: pp. 599, 600.

PLATE XLIX.

Outline Map of part of the western coast of South America to illustrate Mr. Darwin's memoir on the connexion of certain volcanic phenomena in South America; and on the formation of Mountain Chains and Volcanos, as the effect of the same Power by which Continents are elevated: p. 601 *et seq.*

WOOD-CUTS.

Diagrams copied principally from Mr. Hopkin's memoir on Researches in Physical Geology, (Trans. Phil. Soc. Cambridge, vol. vi. pp. 45, 51.) to illustrate slow elevatory movements in the formation of mountain-chains: p. 625.

Diagram explanatory of the effect which would be produced if the thickness of the crust of the earth, upturned by elevatory movements, were equal to the distance between the anticlinal lines: p. 627.

PLATES L. to LVIII.

Illustrate Prof. Sedgwick and Mr. Murchison's memoirs on the Physical Structure of Devonshire, and on the Subdivisions and Geological Relations of its older stratified deposits: p. 633 *et seq.*

EXPLANATION OF THE PLATES AND WOOD-CUTS.

Plates L. and LI.

Map and Sections of Devonshire and Cornwall.

Plates LII. to LVII.

Organic remains engraved and described by Mr. James de Carle Sowerby. May, 1840.

Plate LII.

(Fossils from Barnstaple.)

Fig. 1. *Posidonia* (Bronn.) *lateralis.* Compressed, transversely elongate-ovate, concentrically ridged; umbones very near the anterior extremity; ridges angular. Width about $2\frac{1}{2}$ times the length, which is $1\frac{3}{4}$ inch.

Loc. Venn Lime Quarry, near Barnstaple.

Fig. 2 and 3. *Posidonia Becheri.* (Goldf. Petref. 119. t. cxiii. f. 6 *a.* Bronn. Leonh. Zeitsch. f. Mineralog. 1828, April, t. ii. f. 1—4.)

Compressed, ovate, concentrically ridged, and finely striated; posterior slope straight; ridges numerous; umbones nearest the anterior side. Width in proportion to the length as 7 to 4. Its length is about $1\frac{3}{4}$ inch.

Fig. 3 is from a specimen with fewer ribs.

Loc. Venn Quarry. Swimbridge Quarry.

Fig. 4. *Posidonia Becheri,* var. (Goldf. *loc. cit.* f. 6 *b. c.*) Slightly convex, obovate, with the posterior extremity nearly square; concentrically ridged and finely striated; umbones close to the anterior extremity. Width rather more than the length, which is nearly $1\frac{1}{8}$ inch.

Loc. Venn Quarry.

We have seen specimens of this shell from Herborn, near Dillenberg, and Schelke in Westphalia, where other species of the genus are also found.

We can hardly believe this and the preceding to be the same species; but we yield to Goldfuss, who has had more specimens to examine than have come under our observation.

Fig. 5. *Posidonia tuberculata.* Compressed, obovate, approaching orbicular, concentrically ridged, and marked down the middle with three or four longitudinal ribs, which form more or less distinct tubercles as they cross the ridges. Length not $2\frac{1}{4}$ inches, and width full $2\frac{3}{4}$ inches.

Loc. The specimen figured is from Buddle, near Bamborough.

We have examined one from Devonshire, which has the tubercles much more strongly marked.

Fig. 6 and 7. *Orthoceras cylindraceum.* A much elongated, smooth species, with rather distant septa. The specimens are too imperfect to be positively identified; the name must therefore be considered only as temporary.

Loc. Venn and Swimbridge Quarries.

Fig. 8 and 9. *Goniatites carbonarius.* Although we have seen many specimens of

this shell, they have been mostly sections in various oblique directions, so that we have been unable to determine satisfactorily its shape or the form of its septa; all that we can ascertain is, that the general form of the shell is a depressed spheroid, with a large angular umbilicus, sinuated septa, and a smooth surface. It does not agree with any described by Count Munster.

Loc. Venn Quarry?

Fig. 9 represents, upon the same mass with a specimen of *G. carbonarius*, two small individuals which resemble the *G. stenolobus* of Phillips, (Geol. of Yorkshire, Pl. XX. f. 7–9.); but they are still more globose, have a finely striated surface and a small umbilicus.

Plate LIII.

(Fossils from Barnstaple, Petherwin, Ilfracombe and Marwood.)

Fig. 1 and 2. *Pecten nexilis.* Suborbicular, slightly convex, inequilateral, finely radiated; ears large, nearly equal, that on the anterior side less distinctly radiated than the other; ribs very numerous, elevated, smooth, and thin.

A pretty species, of which we have seen only one or two specimens. It occurs with *Leptæna caperata* (fig. 4) and several other shells in slate from New Ifracombe near Barnstaple, and Barnstaple.

Fig. 2 is a magnified view of the same.

Fig. 3. *Pecten transversus.* Transversely obovate, very slightly convex, radiated, radii in threes, crossed by numerous regular lines of growth; ears large and nearly equal. Length about 1 inch, width nearly $1\frac{1}{2}$ inch.

The great width of this shell is a prominent feature.

Loc. Barnstaple.

Fig. 4. *Leptæna caperata.* Half-elliptical, very convex, concentrically wrinkled, spinose, margin not much deflected; one valve very convex, the other almost equally concave; hinge-line rather longer than the width of the shell; spines adpressed, those near the hinge-line very long. The concentric rugæ are lost towards the centre of the shell.

Loc. Abundant at Barnstaple and Petherwin; also in New Ilfracombe Road, near Barnstaple.

This species a good deal resembles *L. scabricula* (M.C. t. 69, f. 1.), but is well distinguished by the numerous concentric rugæ and the smallness of its spines.

Fig. 5, 16. *Leptæna sordida.* Transversely elongated, rather convex, irregularly striated, hispid? muscular impressions occupying half the internal area; hinge-line nearly as long as the width of the shell, its angles rounded. Width variable, sometimes nearly double the length.

Of this shell we have but very imperfect specimens, and the exterior is badly preserved; the portions which remain show it to have been very irregular. These specimens have been inadvertently engraved with fossils from Barnstaple.

Loc. Linton.

Fig. 6. *Atrypa oblonga.* Oblong-oval, convex, smooth; front produced, elevated; the elevation narrow.

Loc. Barnstaple.

Fig. 7. *Spirifera calcarata.* Semicircular, with extended cuspidate smooth sides, sulcated, very convex; front scarcely at all elevated; ribs numerous, rounded, with about nine on the front bounded by two deep furrows; area probably very narrow. Width more than twice the length.

This approaches closely to *S. attenuata*, M. C., but is distinguished by the sudden contraction of the sides, and the very slight elevation of the front; still we have some doubts of its being distinct from the many varieties of that species. The characters are taken from a single internal cast.

Loc. Barnstaple.

Fig. 8. *Spirifera disjuncta.* This, which is a cast of the inside of the upper valve, appears to belong to the species thus named, and is a good illustration of the internal structure of the genus, exhibiting the beak, the muscular impressions, the central striated foramen, and also the hinge area with its striated structure.

For a further description, see Pl. LIV. figs. 12 and 13.

Loc. Barnstaple.

Fig. 9. *Spirifera inornata.* Fusiform, compressed, smooth, obscurely radiated on the sides; the front even; beaks obscure. Length scarcely more than $\frac{1}{4}$ of the width.

This is so much crushed and distorted, that it is impossible to give a full description; but it appears to be distinct from every other species, approaching nearest in form to the *Orthis* (*Spirifera*) *alata* of the Silurian System, Pl. 22, f. 7.

Loc. Ilfracombe.

Fig. 10. *Orthis plicata.* Transversely elongated, depressed, plaited; plaits numerous, sharp; width twice the length.

This resembles *O. radians* (Silur. Syst. Pl. 22, f. 11), but has much more numerous plaits.

Loc. Barnstaple.

Fig. 11. *Orthis interlineata.* A distorted cast, which may easily be mistaken for *O. canalis* (Silur. Syst. Pl. 22, fig. 8) or *O. testudinaria* (figs. 9 and 10).

Fuller details are given in the description of the Petherwin fossils, Pl. LIV., Fig. 14., where better specimens are figured.

Loc. Leary, N. Devon, &c.

Figs. 12—15. *Calymene.* Figs. 12, 13, 15, Barnstaple. 14, Saunton.

Figs. 17—21. Crinoidal remains. 17, Barnstaple. 18, 19, 21, Redruthen Steps, in St. Eval. 20, Lower St. Columb, Perth.

Fig. 22. *Avicula Damnoniensis.* Obliquely ovate, with a square projecting ear, very convex, short, striated; anterior side small, obtuse; hinge-line rather shorter than the width of the shell; beaks large, convex near the anterior extremity; posterior slope and ear destitute of the fine longitudinal striæ which ornament the rest of the shell.

Abundant in the soft ferruginous sandstone in which the fossils of Marwood Quarry are all imbedded.

Fig. 23. *Cucullæa unilateralis.* Obliquely ovate, gibbose, smooth; posterior side oblique, flattened; beaks nearest to the anterior side.

The cast figured shows the impression of the internal lamina peculiar to the genus.

The species is very abundant.

Loc. Marwood Quarry, where the shells of this and the following species of *Cucullæa* are often replaced by quartz.

Fig. 24. *Cucullæa Trapezium.* Transverse, obtusely trapezoidal, oblong, irregularly convex, smooth; anterior side rounded; posterior large, truncated, and longer than the rest of the shell. Length about $\frac{2}{3}$ths of the width.

Loc. Marwood Quarry. Scarce.

Fig. 25. *Cucullæa angusta.* Squarish, rather wider than long, convex, smooth; anterior side rounded, the posterior truncated, square; beaks central.

A cast has the impressions of the lateral teeth, which confirm the genus.

Loc. Marwood Quarry.

Figs. 26, 27. *Cucullæa Hardingii.* Transversely oval, with the posterior side truncated, gibbose, smooth, nearly twice as wide as long; beaks nearest the anterior side.

Loc. Marwood Quarry.

Fig. 27 is an end view of a smaller specimen.

Fig. 28. *Pullastra? antiqua.* Transversely elongato-ovate, slightly convex, concentrically striated, striæ distant; posterior extremity slightly and obliquely truncated. Length about $\frac{1}{2}$ the width.

Loc. Marwood Quarry.

Fig. 29. *Leptæna prælonga.* Obovate, longer than wide, convex, with a depression along the middle, coarsely and irregularly striated; beak of the larger valve inflated and overhanging the smaller one, which is concave; margin much deflected; hinge-line shorter than the width of the shell; a few slight concentric waves proceed from it.

Loc. Croyde Bay, in a harder stone than the Marwood Bay fossils.

Fig. 30. *Bellerophon globatus.* (Silur. Syst. Pl. III. fig. 15.) We can perceive no difference between this fossil and some specimens from the lower beds of the old red sandstone.

Loc. Marwood.

Fig. 31. Crinoidal casts abundant at Croyde Bay.

Plate LIV.

Fig. 1. *Avicula* (*Monotis*, Bronn) *subradiata.* Obliquely ovate, with one rectangular ear smooth, with a few concentric lines, and radiated principally along the middle; one valve flat, the other convex; anterior extremity rounded, small. Width considerably more than the length.

Loc. Petherwin. Frequent.

Fig. 2. *Avicula Pectinoides.* Suborbicular, flattish, radiated; ears very large, square; the posterior slightly sinuated.

This specimen, which is very imperfect and worn, resembles *A. Neptuni* (Goldf. Pet. CCXVI. fig. 4), but wants the numerous concentric striæ which ornament that

species. We possess fragments which retain this structure, but are not sure they belong to the present species.

Loc. Petherwin, Barnstaple.

Fig. 3. *Leptæna Fragaria*, var. If this fossil be referrible to the species described in Pl. LVI. figs. 5, 6, it is a very strongly-marked variety; but we are not satisfied that it is a distinct species, although the tubercles are more elongated—allowance must be made for the state of preservation.

Loc. Petherwin (abundant).

Fig. 4. *Atrypa hispida.* Transversely oval, compressed, furnished with concentric fringes of spines.

Loc. Petherwin.

Fig. 5. *Atrypa decussata.* Subglobose, slightly compressed; front even, straight; surface concentrically striated and decussated; beak of the lower valve very little prominent, with a trifling angle on each side.

Loc. Petherwin.

Fig. 6. *Atrypa indentata.* Transverse, obovate, with an indented front; the edge of the lower valve elevated; its beak small, prominent.

The front of this shell appears as if impressed by the finger, whence its name: the elevation in the margin of the lower valve does not affect the surface of the other; this may serve to distinguish it from *A. obovata* (Silur. Syst. Pl. VIII. fig. 9), to which it bears a very close affinity.

Loc. Petherwin (with the last, abundant), Barnstaple.

Fig. 7. *Atrypa subdentata.* Orbicular, slightly convex, rather longer than wide, with a pointed three-plaited raised front; beak minute.

Loc. Petherwin.

Fig. 8. *Atrypa Unguiculus.* Hemispherical, rather wider than long, with an inflated beak, smooth; front emarginate; lower valve very convex, its beak channelled; upper flat, with a central impressed line.

This pretty shell occurs abundantly in the Petherwin strata, and is very characteristic of them; it is frequently twice the size of the specimen figured.

Loc. Petherwin, Barnstaple.

Fig. 9. *Atrypa triangularis.* Triangular, with two folds in the front, beak scarcely prominent.

Very much crushed and distorted casts in soft ferruginous stone.

Loc. Petherwin.

Fig. 10. *Atrypa striatula.* Suborbicular, convex, finely striated. A large species.

Loc. Petherwin, Barnstaple, Fowey?

Fig. 11. *Spirifera extensa.* Fusiform, convex, radiated; about 7 ribs are elevated in the middle of the upper valve; its beak small; radii numerous, commencing along the hinge-line.

Loc. Barnstaple, Barnstaple Bridge, Saunton, Petherwin.

Figs. 12, 13. *Spirifera disjuncta.* Semicircular, with an emarginate front, very convex, radiated; upper valve with about 12 ribs, much raised in the front, forming

a rounded elevation; ribs rounded, numerous, about 25 on each side the middle; beaks remote; hinge-area broad, curved, its edges nearly parallel.

This differs from *S. bisulcata* (M. C. t. 494, f. 1) in its less convexity, more numerous striæ, and broader hinge-area; and from *S. bisulcata* of Phillips (Geol. of Yorkshire, Pl. IX. fig. 14), not of M. C. (which it very nearly resembles), in the greater regularity and number of the ribs *.

The specimens of this shell are so generally distorted, that its true form is seldom to be clearly made out; and this, added to the difficulty which already exists of determining between the most perfect specimens of different species, renders it very difficult to ascertain to what species they belong. Perhaps even the *S. gigantea* from Tintagel (Pl. LV. figs. 1 to 4) may be distorted individuals of this species.

Loc. Barnstaple and Petherwin.

Fig. 14. *Orthis interlineata.* Suborbicular, compressed, with the front straight, finely radiated, marked with lines of growth interrupting the radii, which increase in number towards the margin; larger valve not very convex; its beak but slightly prominent; the smaller valve with a shallow depression; muscular impressions nearly parallel in the convex valve, impressions of the hinge-teeth in the other, broad.

This species, when its internal structure is considered, forms a link serving to connect five species already described in the Silurian System. In the irregularity of its striæ, and apparently wide form, it approaches *O. lata* (Silur. Syst. Pl. XXII. fig. 10); in the depression and hinge-teeth of the lower or flatter valve it resembles the *O. orbicularis* of the Upper Ludlow (Pl. V. fig. 16), and *O. canalis* of the Lower Silurian (Pl. XX. fig. 8); and these species are the exact analogues of the *O. lunata* of the Ludlow (Pl. V. fig. 15), and the *O. testudinaria* of the Caradoc (Pl. XX. figs. 9, 10): all of which, by a careful study of their internal characters, may be at once decided upon when all other characters fail.

Loc. Petherwin (abundant), Leary, N. Devon, Barnstaple, Morebath, Landlake, Cornwall.

Fig. 15. *Atrypa fallax.* (*Ter. pleurodon. a.* Phill. loc. cit. t. xii. figs. 25, 26.) This species so exactly agrees with specimens of an *Atrypa* we have from Preston by favour of W. Gilbertson, Esq., that we cannot doubt its identity; and this appears to be a shell that Professor Phillips has united with several others, under the name of *Ter. pleurodon*; it is, however, a genuine *Atrypa*, though so like the genus *Terebratula* that we have designated it *fallax*.

Loc. Petherwin, Barnstaple.

Fig. 16. *Pleurotomaria aspera.* Conical, short; whorls convex with a rounded keel, marked above the band by four principal, and as many intermediate ridges, and beneath it by several smaller ones, all crossed by sharp laminæ, which produce a reticulated surface; band narrow, reticulated.

* The *Terebratulites aperturatus* (Schloth. Nachtr. t. XVII. fig. 1) differs from this species in having a strong rib on each side the depression in the lower valve, and in possessing a triangular area. It is abundant in the Eifel, and much resembles the shell before us.

A handsome shell an inch in diameter.

Loc. Petherwin; Landlake, Cornwall.

Fig. 17. *Terebra nexilis.* Subulate, acute, longitudinally striated; whorls flat; striæ gently bent twice.

A neat shell, much resembling *Rissoa Lefebvrei* (Levéillé in Mém. de la Soc. Géol. de France, vol. ii. part 1, p. 40, Pl. II. fig. 25); but the striæ are finer, the shell more elongated, and the sides of the whorls flatter, than in the specimens we have examined of that fossil.

Loc. Petherwin (frequent).

Fig. 18. *Goniatites vinctum.* Discoid; inner volutions two-thirds exposed; sides of the whorls flat; their inner edges abrupt; front rounded, encircled by a thread-like keel; inner whorls crossed by straight undulations; lobes of the sépta three on each side, that on the middle of each side by far the longest; ovate, pointed.

The specimen before us, though very imperfect, is clearly distinguished from *G. Henslowi* (M. C. t. 292), by having but three instead of four lobes on each side; and from *G. subarmatus,* (Munster, Plan. und Goniat. Tab. VI. f. 2.) to which it is closely allied, by the ovate form of the lobes, which in that fossil have their sides straight, and the whorls in that species do not increase so rapidly.

We have had the good fortune to see, in the Rev. Mr. Williams's rich collection of Cornish fossils, several new and interesting species of *Goniatites* and *Clymenia* in company with a species resembling *Nautilus* (*Goniatites?*) *complanatus* (M. C. t. 261.), which he has however reserved for future publication.

Fig. 19. *Clymenia* (*Endosiphonites,* Ansted) *lævigata.* (*Planulites lævigatus,* Munster, Plan. und Goniat. T. I. f. 1.) A large smooth shell, with many whorls, and only a slight sinus on either side of each septum. Our specimens are not so large as that figured by Count Munster, nor is the wave in the septum placed so near the front of the whorl.

Fig. 19 *a. Clymenia linearis.* (*Pl. linearis,* Munst. loc. cit. T. II. f. 5, 6. *Endosiphonites carinatus* and *minutus.* Ansted Camb. Phil. Trans. vol. vi. Pl. VIII. f. 1, 2, 3.)

This well-marked species is abundant in the Petherwin beds, and is distinguished from the preceding by the deep acute-angled sinus in the side of the septum, and also by its striated surface and linear keel.

Having examined the Cambridge specimens, we can see no reason for supposing the *E. minutus* a distinct species, especially as we have found on it the characteristic keel of *E. linearis,* or for altering the original specific name given by Count Munster.

Loc. Petherwin.

Fig. 20. *Orthoceras striatulum.* Rather rapidly tapering, ornamented with prominent transverse rings, crossed by numerous fine threads, which alternate with still finer lines; annulations sharp, oblique, rather more distant than the septa.

This has a close affinity with *Orthoceras Tubicinella* of the *Plymouth limestone* (Pl. LVII. f. 29.); but the threads are closer and finer, and it appears to be a larger species. At first sight it looks much like *C. annulatum* (M. C. t. 133.); but the longitudinal lines, and want of transverse scales, easily distinguish it.

Loc. Petherwin. It appears to be abundant, and very variable in size.

Fig. 21. *Orthoceras.* This specimen, though very imperfect, was figured on account of the very curious longitudinal mark which crosses the edges of the septa, giving it the aspect of the alveolus of a *Belemnite*.

Fig. 22. *Orthoceras.* A remarkably crushed specimen, so as to resemble a form of *Belemnite* common in the Lias. Similar occurrences are not unfrequent in the Upper Ludlow Rock of the Silurian series.

Figs. 23, 24. Fragments of two species of *Calymene*. Fig. 24 much resembles *C. tuberculata* (Silur. Syst. Pl. XIV. fig. 4.), but differs from that species in the number of lenses to the eye, which are but few in the present specimen. Similar fragments are not very uncommon in a soft stone at Petherwin.

Plate LV.

Figs. 1 to 4. *Spirifera gigantea.* Convex, radiated; sides cuspidate; radii numerous, proceeding from the hinge-line; about nine or ten are elevated in the front, which is deeply emarginate; lines of growth rather conspicuous, crossing the ribs.

This magnificent species, which occurs nearly nine inches wide in micaceous slate at Tintagel, seems to be intermediate in character between *S. disjuncta* Pl. LIV. f. 12, 13, and *S. calcarata*, Pl. LIII. f. 7. The specimens we have examined are all destitute of shell, and the casts are covered with plates of mica, which lie flat on the surface and give it a glittering aspect; and they are so distorted in the direction in which the slate has been pressed, that they may easily be taken for many different species. The ribs are about as numerous as in the *S. Verneuillii*, and are very regular.

Fig. 1 is a specimen pressed laterally and flattened; a cast of the interior of the lower valve, natural size.

Fig. 2 is a young individual, showing the outside of the same valve; natural size.

Fig. 3 is a specimen of the same valve, reduced to half its length.

Fig. 4 shows the upper valve laterally compressed, and folded down upon one of its sides; natural size.

We have already given our opinion that this may be the *S. Barumensis*, but the cuspidate sides may probably entitle it to rank as a distinct species.

Loc. Tintagel.

Figs. 5 to 7. *Spirifera costata.* (*S. speciosa* of the Eifel?) Elongated-fusiform, convex, costated; costæ prominent, thick, about five or six on each side the middle, in which two are elevated and approximate; lower valve with a deep broad depression bounded by two strong ribs; hinge-area broad, its edges parallel. Length not $\frac{1}{6}$th of the width.

The specimens we have seen of this fine *Spirifera* are all imperfect, and we cannot speak with certainty as to the surface; lines of growth appear to cross the ribs, but they may be plaits occasioned by pressure.

Occurs with groups of corals, fragments, &c., in a soft slaty stone at Fowey, and at Tintagel in a hard blue slate with the former species, and at Looe.

Fig. 8. Part of the *pelvis* of a crinoidal animal.

Occurs in a hard, flinty, slate rock, traversed by veins of Quartz at Looe.

Plate LVI.

Fig. 1. *Corbula Hennahii.* Transversely elongate-ovate, with a slightly projecting beak, smooth, convex, valves somewhat unequal; posterior side obliquely truncated, anterior pointed; twice as wide as long.

There appears no likelihood to us of this shell being referrible to the genus *Lembulus*, to which it was assigned by Dr. Leach; its unequal valves, if this be not accidental, indicate its affinity to *Corbula*.

Loc. Mount Wise.

Fig. 2. *Cardium aliforme*, var. (M. C. t. 552. f. 2. Goldf. Petr. 213. Tab. CXLII. f. 1. *Pleurorhynchus minax* and *aliforme* of Phillips, Geol. of Yorks. 210. Pl. V. f. 27. *Bucardites hystericus*, Schloth. Nachtrage. t. XX. f. 1.) One of the many varieties of *C. aliforme*. Goldfuss has done well in keeping them all together. We can see no reason for separating them into distinct species, or for adopting a new generic name.

Loc. Stonehouse Hill.

Fig. 3. *Leptæna analoga.* (Phill. loc. cit. Pl. VII. f. 10. *Producta anomala*, Sowerby. See Encyc. Metrop. loc. cit.) The worn specimen before us we presume to belong to this species. We have seen a most beautiful internal cast from Barnstaple in the collection of the Rev. D. Williams.

Loc. Plymouth, Barnstaple.

Fig. 4. *Leptæna rugosa*, His.? (Dalm. Act. Holm. 1827, 106. Tab. I. f. 1.) We refer this shell with uncertainty to Dalman's species, of which we have not seen well-authenticated specimens; its more even form distinguishes it from *L. depressa*. (M. C. t. 459. f. 3.)

Loc. Plymouth.

Fig. 5. *Leptæna Fragaria.* Hemispherical, with slightly projecting sides, concentrically waved, nearly smooth, pustulated; beak of the convex valve pointed; hinge-line rather shorter than the width of the shell.

This species approaches very closely to *Producta pustulosa* (Ph. loc. cit. Pl. VII. f. 15.), or perhaps more nearly to *P. rugata* (Ph. Pl. VII. f. 16.); but, wanting the deep concentric rugæ which mark these species, we have called it *Fragaria*, from the collection of pustulose tubercles (probably the bases of spines) which cover its surface pretty regularly; it is however highly probable that all are varieties of one species.

Loc. Plymouth, Petherwin?

Fig. 6 is probably the young of the preceding species; the tubercles are more numerous in proportion to the size.

Loc. Plymouth.

Fig. 7. *Leptæna interrupta.* Semicircular, very gibbose, concentrically ribbed; longi-

tudinally and finely striated; striæ interrupted by the concentric ribs; hinge-line equal to the width of the shell; beak somewhat produced.

A small species, nearly akin to *L. punctata* (M. C. t. 323).

Loc. Plymouth.

Fig. 8. *Atrypa juvenis.* Broad-ovate, slightly convex, smooth, curved, longer than wide; front somewhat pointed; valves nearly equal, the lower curved upwards with a minute beak.

A small, rather flat species, distinguished by its narrow front, and by being curved.

Loc. Plymouth.

Fig. 9. *Atrypa lacryma.* Subglobose, smooth, longer than wide; front straight or slightly waved, scarcely raised except at the edge, which is deeply sinuated by the projection of the inferior valve, the central furrow of which is broad, flat and bounded by two sharpish ridges; its beak not prominent; side rounded.

An obscurely-marked species; very convex, and with nearly equal valves.

Loc. Plymouth.

Figs. 10, 11. *Strigocephalus* (Bronn) *giganteus.* (*Terebratula gigantea*, Sowerby. See Encyc. Metrop. loc. cit.)

Suborbicular, convex, smooth, with a straight pointed beak; valves nearly equal; area beneath the beak a right-angled triangle, flat; foramen narrow.

Almost all the specimens we have seen of this noble shell, which is often six inches in diameter, are much distorted; its true form appears to be round. It very nearly resembles the genus *Atrypa*, but differs from it in the presence of an area between the beaks; this species is distinguished by its small straight beak, and its flatter shape, from the *Strigocephalus porrectus*, which is plentiful in the Plymouth limestone, and is (*Ter. porrecta*, M. C. t. 576. f. 1.) *Strigoc. Burtini* of continental authors.

A specimen with a slight depression along the lower valve we once distinguished by the name of *Ter. Hennahiana* (see Encyc. Metrop. loc. cit.), but subsequent examination has shown it to be a variety.

In some internal casts the muscular impressions appear to have been strong, and the shell has been coated inside with rhomboidal crystals of carbonate of lime, which give it a decussated appearance.

Loc. Plymouth, Newton Bushell.

Figs. 12, 13. *Atrypa plebeia.* Transversely obovate, with a produced front, smooth, not very convex; front slightly elevated, without a depression in the lower valve; beak but little prominent.

This is a common species and varies in form; it was formerly (see Ency. Metrop. loc. cit.) considered to be the young of *A. glabra* (M. C. 269. f. 1.), but the regular convexity of the lower valve and small beaks distinguish it.

Loc. Mount Wise, Plymouth.

Fig. 14. *Atrypa triloba.* Tetrahedral, with rounded angles, 3-lobed, plaited; upper valve extremely gibbous; lower nearly flat; front much elevated, with about 12

plaits, its sides smooth; lateral lobes reflexed, obscurely plaited. Length and width nearly equal, the depth rather less.

Somewhat resembling the most extravagant but small varieties of *A. Pugnus* (M. C. t. 497.); but it is more triangular, the plaits are rounder, less elevated, continued almost to the beak, and more numerous; it is more like *T. flexistria* (Ph. *loc. cit.* Pl. XII. f. 33, 34.).

A handsome shell.

Loc. Plymouth.

Fig. 15. *Atrypa Pugnus* (M. C. t. 497.). A flattened variety of this very variable species. See also Fig. 18.

Loc. Plymouth.

Fig. 16. *Atrypa protracta.* Triangular, longer than wide, lateral angles rounded; beak produced acute; sides flattened, front elevated with about 4 plaits, its sides smooth.

Loc. Plymouth.

Fig. 17. *Atrypa crenulata.* Pentagonal, compressed, smooth; front broadly and suddenly elevated, crenulated by numerous small plaits near its margin; sides smooth; beak scarcely any. A neat species.

Fig. 18. *Atrypa Pugnus* (M. C. t. 497.). Another variety of the mountain-limestone shell, rather narrower than usual; other varieties also occur here.

Loc. Mount Wise.

Figs. 19 and 20. *Atrypa desquamata.* Oblong, with a straight front, gibbous, deeply striated; striæ increasing in number towards the margin; front obtuse, gently and broadly raised at the edge without elevating the surface; shell longer than wide; upper valve deeper than the one with the projecting beak.

This shell, which is very abundant in the Plymouth limestone, varies exceedingly in size, coarseness of striæ, and convexity. In some young individuals the form is nearly globose, while in others it is compressed and lenticular.

Loc. Plymouth.

Figs. 21 and 22. *Atrypa desquamata* var. *compressa.* Suborbicular, compressed; sides nearly rectangular; margin nearly even; valves equal.

This differs from the first variety in being flatter and broader; the upper valve, not being very convex, does not hang over the beak of the lower so much as in the more convex variety (Fig. 20.), wherefore this seems to have a more projecting beak, which, when broken, appears to have a flat area.

Both the varieties approach so near to *A. affinis* (M. C. t. 324.), and more especially to the *Eifel* specimens of that species, that, were it not for the total absence of concentric scales, the much more even margin, and the oval not triangular contour, we should continue to refer them to the same species. One of the varieties was formerly called *T. affinis* (in the Encyc. Metrop. *loc. cit.*).

Fig. 23. This is evidently a young shell; we cannot distinguish it from some specimens of *A. aspera* (Silur. Syst. Pl. XII. f. 5.), but most probably it is a young individual of the *A. desquamata.*

Loc. Plymouth.

Fig. 24. Atrypa cuboides. Subglobose, striated; front raised, very flat, with a deep square sinus in the margin, edges sharp, projecting; striæ numerous, shallow, about 15 are elevated; beak small, acute; lower valve small, nearly flat, with a large projecting square appendage filling the sinus in the upper one; striæ numerous, shallow, extending to the beaks, those on the side much curved.

The parallel striæ on the front are a striking character.

Loc. Plymouth, also in the Eifel.

Fig. 25. Atrypa latissima. Transversely elongated, smooth, convex, with rather pointed dependent sides; front elevated, broad, rounded and furrowed, furrows shallow, many very obscure on the sides.

Nearly related to *A. platyloba* (M. C. t. 496, f. 5, 6.), but the front is rounder, and the furrows much less distinct.

Loc. Plymouth.

Plate LVII.

Fig. 1. Atrypa squamosa. Lenticular, ribbed, squamose.

The ribs are thick, sometimes forked, and are crossed by concentric thin laminæ; they vary in number, and are sometimes so numerous that it is difficult to draw a line of demarcation between this species and *T. aspera* of Schlotheim, which again passes into *A. affinis* (Silur. Syst. Pl. VI. f. 5. M. C. t. 324.).

Loc. Plymouth.

This shell appears to characterize a stratum of limestone in the Eifel.

Fig. 2. Atrypa impleta. Transversely elongated, ventricose, furrowed; sides rounded; front elevated with six furrows; beaks slightly prominent, much wider than long.

The furrows on the surface are shallow and extend to the beaks, the ribs between them are rounded.

Loc. Plymouth.

Fig. 3. Atrypa sphærica. Spherical or rather obovate, transverse, ventricose, plaited; edge of the front deeply sinuated, with five elevated ribs; beak small, adpressed. Rather wider than long.

Loc. Plymouth.

Fig. 4. Atrypa implexa. Obovate, transverse, plaited. Front straight, flat; margin of the front and sides broad; the toothed edges of the valves deeply locked into each other; plaits numerous, acute.

At first sight this may be taken for *Atrypa Wilsoni* (M. C.), but it is not so cylindrical, neither is the front so deeply sinuated.

Loc. Plymouth and the Eifel.

Figs. 5 and 6. *Atrypa primipilaris*, Schloth. (Von Buch. Terebr. 68, T. II. p. 29. *Spirifer pentagonus*, Sower. See Encyc. Metrop. *loc. cit.*) Pentagonal, convex, plaited; front elevated, with three or more plaits, margin flattened; a deep angular furrow runs along the middle of the lower valve, bounded by two angular ridges; beak prominent. Fig. 6 represents a young shell.

Loc. Plymouth, Eifel.

Fig. 7. Spirifera (?) *crenistria*, Phill. (Geol. of Yorksh., 216, Pl. IX. f. 6. *Sp. reticu-*

lata, Sowerby. See Encycl. Metrop., *loc. cit.*) This shell is not very uncommon in the mountain-limestone of the north of England and of Ireland; it also occurs at Matlock. The Irish specimens are often large, with deflected margins, which, with other circumstances, induce us to believe this shell will prove to be a *Leptæna*.

Loc. Plymouth.

Fig. 8. *Spirifera nuda*. Semicircular, with prominent beaks, smooth, the middle elevated, with a furrow on each side of it; edge obtuse.

Loc. Plymouth.

Fig. 9. *Spirifera pulchella*. Hemispherical, convex, smooth, with three large rounded ribs; edge sinuated; beak of the lower valve large, incurved.

This resembles *Sp. crispa* (Silur. Syst., Pl. XII. f. 8.), but is smooth and has fewer ribs.

Loc. Plymouth.

Fig. 10. *Spirifera subconica*, var. (*Anomites subconicus*, Mart. Pet. Derb. Pl. XLV. f. 6.) This is smaller and has a more curved beak than Martin's shell, but we think it is the same species.

Loc. Plymouth.

Fig. 11. *Spirifera affinis*. Lenticular, ribbed, ribs numerous, branched and crossed by concentric thin laminæ; hinge-line shorter than the width of the shell; beak of the lower valve prominent, with a triangular flat area.

The prominent beak and large triangular area distinguish this from *Atrypa aspera*, Schloth. (Silur. Syst., Pl. XII. f. 5.) which it much resembles; it is a remarkable shell.

Loc. Plymouth.

Fig. 12. *Orthis tenuistriata*. Semicircular, with the front straight, striated; one valve regularly convex, the other flatter; hinge-area parallel, narrow.

The fineness of the striæ and the regular convexity, joined with the parallel area, at once distinguish this and make us doubtful whether it be not a *Leptæna*; traces of spines are indistinctly visible.

Loc. Morebath.

Fig. 13. *Pileopsis vetusta* (M. C. t. 607). The specimen figured is more involute and even than the shell in Min. Conch., but examples pretty frequently occur much more like that figure at Mount Wise, &c.

Loc. Plymouth.

Fig. 14. *Nerita deformis*. Subhemispherical, obliquely flattened; whorls rapidly increasing, finely striated; inner lip uneven, aperture ovate.

This was formerly published (see Encyc. Metrop., *loc. cit.*) under the name of *N. spirata* (M. C. t. 463, f. 1, 2.); but it is not so transverse or ventricose, and the spire, though imperfect, could not have been so depressed.

Loc. Stonehouse Hill.

Fig. 15. *Nerita speciosa*. Conical, depressed, smooth?; whorls rapidly increasing, the upper ones very convex, the lower rather square, with a central spiral depression above, concave beneath; aperture subtrapezoidal? Height and diameter about equal, often 3 inches.

This fine shell was published (see Encyc. Metrop., *loc. cit.*) as a var. of *N. spirata*; but the size of the spire, the square form of the lower whorls, and its great size, entitle it to the rank of a species.

Loc. Mount Wise, Plymouth, where it occurs of all sizes.

Fig. 16. *Pleurotomaria impendens.* Conical, short, spirally striated, base concave; whorls rather flat above,—the lower overhung by the angular base of the preceding whorl; the striæ which encircle the whorls are less distinct towards the upper margin.

The imperfect specimens we possess of this shell will not allow us to draw up a full description.

Loc. Plymouth.

Fig. 17. *Pleurotomaria cirriformis?* (M. C. t. 171, f. 2. *Euomphalus delphinuloides?* Auct.) An imperfect water-worn cast is all we possess of this shell; the true *P. cirriformis* is found at Paffrath, and has the above name applied to it by continental authors.

Loc. Plymouth, also in the mountain-limestone.

Fig. 18. *Turbo subangulatus.* Conical, elongated; whorls about six, convex, marked with three obscure spiral ridges on each; aperture nearly circular.

This which occurs with the last is in the same bad state of preservation.

Loc. Plymouth.

Figs. 19 and 20. *Turbo cirriformis,* Sower. (see Encyc. Metrop., *loc. cit.*) Conical, short, oblique, smooth; apex obtuse; whorls slightly rounded, most prominent below; aperture circular. Height and diameter equal, about $\frac{1}{8}$ an inch.

An obscure, yet neat species, common at Stonehouse Hill.

Fig. 21. *Murex Harpula* (M. C. t. 578, f. 5.). Young individuals of this pretty species are frequent in the Plymouth limestone.

Loc. Stonehouse Hill, also Bradley.

Fig. 22. *Terebra Hennahii,* (*Ter. Hennahiana,* Sower., see Encyc. Metrop. *loc. cit.*). Subulate, longitudinally and very finely striated, whorls slightly convex, striæ gently bent twice. Diameter not much above $\frac{1}{4}$ of the height, which is but $\frac{3}{8}$ths of an inch.

Very like *T. nexilis* of the Petherwin beds (Pl. LIV. f. 17.), but with still finer and less bent striæ, so that *Rissoa Lefebvrei, T. nexilis,* and the present species will form a neat series of species characteristic of these beds.

Loc. Stonehouse Hill.

Fig. 23. *Buccinum acutum* (M. C. t. 566, f. 1.). This is very imperfect, but cannot be distinguished from the shell figured in Min. Conch., which is found in Queen's County, Ireland.

Loc. Stonehouse Hill.

Fig. 23 *a. Buccinum imbricatum* (M. C. t. 566, f. 2.). Imperfect specimens, common in this locality.

Loc. Stonehouse Hill, also Bradley, near Newton Bushel.

Figs. 24 to 27. *Buccinum spinosum* (M. C. t. 566, f. 4.). These specimens are variously distorted, but are all evidently referrible to this species, which we have seen also

from the Eifel, and we may remark, that this locality presents the most complete analogy with the Devonian beds.

Loc. Plymouth and Bradley, frequent.

Fig. 28. *Orthoceras cylindraceum*? An imperfect specimen. We have called it the same as that in the black limestone of N. Devon (Pl. LII. f. 6, 7), though the smooth species are so much alike that without good specimens we would not pretend to determine positively any one.

Loc. Newton Bushel, with *Brontes flabellifer*, Goldf.

Fig. 29. *Orthoceras Tubicinella*. Slowly tapering, ornamented with prominent transverse oblique rings, which are crossed by numerous thread-like ribs without intermediate ones, giving it exactly the aspect of the recent *Tubicinella Balænarum*; section circular.

This very pretty species bears a good deal of resemblance to *O. striatulum* (Pl. LIV. f. 20), but the longitudinal ribs are much thicker and more prominent than in that species; it resembles too the *O. rugosum*, Flem. (Phill. *l. c.*, Pl. XXI. f. 16.), but in that beautiful shell the rings are more distant, and the longitudinal ribs are elevated into spines at short intervals.

Loc. Plymouth.

Fig. 30. Remains of an *Asaphus* or *Trinucleus*? common at Newton Bushel.

It is remarkable that no trace of the position of the eyes remains on the cast, which is also the case with the genus *Trinucleus*, Murchison.

Fig. 31. Pelvis of *Cupressocrinites*? We have seen two specimens of the pelvis in the Plymouth limestone, and one of the arm of this curious animal from Collumpton, where also large specimens of *Brontes flabellifer* occur.

Loc. Plymouth, Collumpton,

Plate LVIII.

Corals from the limestones south of Dartmoor, described by Mr. Lonsdale. The specimens are principally in the cabinets of Mr. Austen, Mr. Daniel Sharpe, the Rev. R. Hennah, and the Woodwardian Museum, Cambridge.

Fig. 1, 1 *a*. *Astrea pentagona* (De Blainville, Man. d'Actinologie, p. 375).

Cyathophyllum pentagonum (Goldfuss, Petref. p. 60, Tab. 19, f. 3.).

Stars irregular in size and shape, but well defined, both on the weathered surface (Fig. 1.) and in a polished section (Fig. 1 *a*.), the boundaries being formed by zig-zag lines connecting the ends of the rays. On a weathered surface, the centre of the star presents a radiated boss; but in a polished section it consists of carbonate of lime, into which the longer rays project more or less, according to the state of preservation. Rays numerous, equal in breadth and uniform in character, but alternately long and short, the termination of the latter assisting to define the centre of the star. From the irregularity in the shape of the star, the length of the rays varies considerably. Character of the perfect terminal star not known.

Loc. Newton Bushel, Torquay, Plymouth.

Fig. 2. *Stromatopora polymorpha* (Goldf. Petref. Tab. 64, f. 8.). Form irregular, mammillated or branched; composed of concentric layers, united at irregular di-

stances by vertical filaments. The horizontal section (Fig. 2.) presents more or less perfectly, perforated centres, from which irregular tubes diverge, also the terminations of the filaments, and portions of the concentric layers.

Loc. Appleway and near Teignmouth.

Fig. 3, 3 b. Astrea Hennahii (Sp. n.).

Stars not defined either on a weathered surface (Fig. 3.) or in a polished section (Fig. 3 *a*.). On the former, the centre of the star presents a radiated boss, in the latter, fine converging lines. Rays about thirty-six, unequal in length and breadth, and of a crenulated structure. The rays of one star unite with those of the adjoining stars, the junctions being more or less regular according to their position with respect to the angles of the stars. The rays are alternately long and short, the latter terminating around the central portion of the star, and the former which swell out at the same boundary suddenly become attenuated beyond it, and are prolonged as fine laminæ to a reticulated centre. The vertical section (Fig. 3.) is composed of perpendicular close-set parallel lamellæ united by innumerable transverse plates (Fig. 3 *b*.).

Loc. Barton Quarry, Newton, Plymouth.

Fig. 4, 4 f. Porites pyriformis, Ehrenberg.

Astrea porosa (Goldfuss, 21, f. 7.) *Porites pyriformis* (Silur. Syst. Pl. XVI. f. 2.).

This fossil abounds in the Devonian limestones as well as in the Silurian system; but specimens of the perfect coral, or in that state in which it is presumed the polype ceased to add to its strong fabric, appear to be very rare. I have seen only a few belonging to Mr. Austen's collection. In the young state, and during the period when additions were made to its vertical dimensions, the coral consisted of circular tubes, with a projecting margin, from which twelve rays proceeded and united in the centre; and the interstices between the circular tubes were occupied by smaller polygonal ones, open at the upper end. In the state in which it is supposed the polype ceased to add to the structure of the coral, the fossil (Fig. 4, 4 *a*. 4 *c*. 4 *d*. 4 *e*.) presents in the place of the circular depressed tubes, a raised boss, the margin of which is a sunken and not a projecting line; and the intervals between the twelve rays of the immature coral are occupied by convex surfaces, separated by fine furrows. These bosses are surrounded at irregular distances by polygonal ridges, giving the coral the aspect of a series of stars in close contact (Fig. 4.). The ridges and the whole of the surface, which in the young specimens consist of open tubes, are formed of convex papillæ preserving in greater or less perfection the angular form of the tube.

The right half of Fig. 4 *c*. exhibits the usual character of the coral, except that the projecting margin of the circular tubes is wanting; the left half of the same specimen presents imperfectly the character of the mature coral. Fig. 4 *d*. has been drawn from a partly polished specimen, the remainder giving examples of the radiated boss, but without the bounding polygonal ridges. Fig. 4 *f*. is a magnified representation of the polished surface, and Fig. 4 *e*. of the bosses. Fig. 4 exhibits the character of the perfect coral, and Fig. 4 *a*. is a magnified portion of the same specimen. Fig. 4 *b*. displays the internal structure of the fossil.

From the above characters, believed to be new among lamelliferous corals, it is inferred that this fossil does not belong to the genus *Porites*; but it has been thought advisable not to propose, at present, a new one for it.

Loc. Newton Bushel, Marychurch, Plymouth, &c.

Figs. 5 to 5 *d.* *Coscinopora placenta*? (Goldfuss, Pl. IX. f. 18.).

Prof. Goldfuss described the fossil which he has called *Coscinopora placenta* from apparently a single and probably an imperfect specimen, and was therefore unable to detail fully its characters. It is with considerable hesitation that the Devonian fossil has been assigned to the same genus and species; but it has been thought better to do so provisionally than to propose a new generic appellation.

The coral represented in Figs. 5 to 5*d.* consists of amorphous masses, composed of very thin concentric layers, traversed horizontally and obliquely by irregular vermiform cavities, and perforated vertically by cylindrical tubes, which penetrate the whole depth of the specimen, and are bounded by a white circle forming the substance of the tube (Figs. 5, 5 *a.* 5 *b.* 5 *d.*). The distance between the layers is about equal to their thickness; and the layers are united by vertical filaments of variable form and dimensions, the interstices having a punctured appearance (Fig. 5 *a.*). In some specimens the vertical section is banded, being crossed by stripes of a darker colour (Fig. 5 *a.*).

This fossil varies greatly in character, according to its state of preservation or mineralization. In some specimens, all structure has nearly disappeared, except the vertical tubes, and the coral then agrees with Goldfuss's description (*C. discoidea, poris orbiculatis æqualibus, interstitiis lævibus*). Other specimens might be mistaken for masses of *Stromatopora concentrica*, except that the tubes with careful search may always be found (Figs. 5 *b.* 5 *c.* 5 *d.*); and the resemblance is still stronger in some masses consisting of gray carbonate of lime, traversed at distant intervals by concentric bands of the decomposed coral.

Loc. Newton Bushel, Torquay, Appleway, Plymouth, &c.

Petraia (Munster, MS.).

Fig. 6. *Petraia Celtica.*

Turbinolia Celtica (Lamouroux, Expos. Méthod. Pl. LVIII. f. 7, 8.). (See *antè*, p. 697.)

Turbinated; external cast smooth?; internal cast composed of thick lamellæ, with two indistinct rows of papillæ and a furrow down the middle.

An abundant coral in the slate rocks of Cornwall, but it rarely presents more than flattened casts of the interior. It is placed in this genus because it agrees generically with specimens labelled *Petraia* from the continental collection of Count Munster.

Loc. Dinas Cove Padstow, Berry Pomeroy, and Fowey.

A large coral differing from the above, principally in size, occurs in slate rocks at New Quay, and near Newton Bushel.

Fig. 7. *Strombodes vermicularis.*

Cyathophyllum vermiculare? (Goldfuss, Petref. Tab. 17, f. 4.).

Cylindrical, straight or curved, externally traversed by vertical ridges, marking

the position of the internal lamellæ, and by concentric rugæ and fine lines (Fig. 7.). Internally formed of numerous lamellæ, which are spirally contorted in the centre, and bifurcate as they radiate more or less regularly to the circumference (Fig. 7 *a*.). No central cavity crossed by chamber-like septæ, that part of the coral being occupied through its whole height by the spiral lamellæ (Fig. 7 *a*.).

Loc. Plymouth and Newton Bushel, abundant.

Figs. 8 to 8 *d*. *Cyathophyllum cæspitosum* (Goldfuss, Tab. 19, f. 2.).

An abundant coral in the Devonian limestones, but seldom well preserved, the exterior portions having been in general removed by atmospheric action. Fig. 8 *a*. represents a common weathered specimen; 8 *c*. a section of a similar branch; 8 *b*. a section of one in which the exterior has been less effectually removed. Fig. 8 represents a specimen of hard limestone, in which the matrix has preserved the exterior portions of the coral. Fig. 8 *d*. is a vertical section, exhibiting transverse chamber-like plates, and part of another branch or individual, which had sprung from a gemmule deposited on the side of the main coral, and not originated in the subdivision of the older animal. The sections, Figures 8 *b*. 8 *c*. and 8 *d*. in the absence of the central style, sufficiently distinguish this coral from one of similar external form, abundant in the mountain-limestone.

Loc. Newton Bushel, Plymouth, Torquay, &c.

Fig. 9. *Scyphia turbinata* (Goldfuss, Petref. Pl. II. f. 13.).

Two pyritous specimens imbedded in slate, from the vicinity of Plymouth, are in the cabinet of the Rev. R. Hennah.

Fig. 10. *Fenestella antiqua*? (Silur. Syst. Pl. XV. f. 15, 18.).

Gorgonia antiqua (Goldfuss, Petref. Pl. XXXVI. f. 19.).

This is also an abundant coral in the slate rocks of the Devonian system; but the essential characters are seldom preserved. It presents generally a more or less delicate net-work (Fig. 10) or cast of the interior surface of the coral; and occasionally impressions of the bifurcated lamellæ of the exterior surface (10 *a*.). Casts of the pores have been also observed in a few instances, and their arrangement led to the belief, when first noticed, that the coral belonged to a new, well-distinguished species of *Fenestella*. Instead of being arranged in two rows, separated by a ridge or projecting angle, as in *Fenestella antiqua* (Silur. Syst. Pl. XV. Fig. 16. Goldf. Pl. XXXVI. f. 9.), the pores or their casts are in contact and disposed alternately, so that the projecting curve of one pore occupies the space between two pores in the adjacent row (Fig. 10 *b*.). On examining however some crushed specimens of *Fenestella* from Meinershagen, the characters of the Devonian coral and of *Fenestella antiqua* were noticed in portions of each specimen; and though the detached fragments could not be proved to have been once united, yet little doubt can exist of their being portions of the same coral, and that the alterations in character must be ascribed to changes in the animal at different periods of growth. Fig. 10 *b*. is a portion of Fig. 10 *a*. mag.

Loc. Petherwin, Fowey, Plymouth, in soft yellow slate, Newton Bushel, Saunton, Linton, &c.

Fig. 11 *to* 11 *b*. *Cystiphyllum Damnoniense* (Sp. n.).

Turbinated or cylindrical; terminal cup occasionally very deep, occasionally shallow, covered with bladder-like tubercles, traversed in some specimens by radiating lamellæ; external surface marked with concentric rugæ and faint vertical lines; internal structure very irregularly vesicular, often without any indications of radiating lamellæ; but in some specimens there are indications of them (Fig. 11 *b.*), and in others they are quite distinct (Fig. 11 *a.*).

Fig. 11 represents a portion of a fine group, with three young corals attached to the side of an old one.

Loc. Newton Bushel, very abundant, the coral occurs also at Plymouth.

WOOD-CUT.

Section from the Foreland in the Bristol Channel to the English Channel: p. 702.

Plates LIX. and LX.

Illustrate Mr. Stokes's paper on some species of *Orthocerata*: p. 705.

Plate LIX.

Fig. 1. *Actinoceras Lyonii*, p. 707.

Figs. 2 and 3. *Actinoceras Richardsonii*, longitudinal and transverse sections, p. 708.

Fig. 4. *Actinoceras Simmsii*, one third the natural size, p. 708.

Fig. 5. Transverse section of *Actinoceras Simmsii*, p. 708, and note †, also p. 712.

Fig. 6. Magnified portion of the coral investing *A. Simmsii*, p. 708, note †, and p. 712.

Plate LX.

Fig. 1. *Ormoceras Bayfieldii*, p. 709.

Fig. 2 and 3. Longitudinal sections of *Huroniæ*, p. 710.

Fig. 4. Exhibits a peculiarity in the structure of *Orthocerata*. The specimen is from Russia, p. 712.

Fig. 5. *Huronia Portlockii*, p. 710.

Plate LXI.

Illustrates Col. Sykes's paper on fossils procured by Capt. Smee and Col. Pottinger in Cutch and the Desert to the north-east of Cutch, p. 715. The shells have been engraved and the description prepared by Mr. James de Carle Sowerby, F.L.S.

Fig 1. *Astarte major*. Elliptical, convex, concentrically furrowed when young; furrows numerous; beaks small, near the anterior side; lunette broad, flat, deeply sunk; ligament long, sunk. Length from 2 inches 4 lines to 2 inches 8 lines, width $4\frac{1}{2}$ inches.

This species varies much in the proportions of its length and breadth, and the anterior side is sometimes formed as if truncated. The figure represents a very wide variety diminished to $\frac{2}{3}$rds its size.

Fig. 2. *Astarte compressa.* Nearly orbicular, wider than long, flattish, concentrically ribbed; lunette deep, small; beaks small, near the anterior side; edge toothed. Length $1\frac{1}{4}$ inch, width 1 inch 5 lines.

A species very closely resembling this is found at Cross Hands in Gloucestershire in the inferior oolite.

Fig. 3, 3 *a.* *Astarte rotunda.* Orbicular, concentrically ribbed; beaks central; lunette sunk; margin toothed. Length 2 lines, width the same.

Nearly like *A. elegans* (M. C. t. 137, f. 3.), but it is so much imbedded in the stone that its characters cannot be clearly determined. Fig. 3 *a.* is magnified.

Fig 4, 4 *a.* *Corbula pectinata.* Trigonal, rounded, gibbose, longitudinally striated, concentrically ribbed; posterior extremity separated in the form of a small lobe, pointed; ribs thin, much elevated. Lunette deeply sunk, not defined; beak incurved. Length and width nearly equal, from $\frac{1}{2}$ an inch to an inch. Fig. 4 shows the impression of the hinge-tooth.

This differs from *Corbula lyrata* (*antè* Grant, Pl. XXI., f. 13.), which is also from Cutch, in having numerous thin striæ and thin ribs. It occurs loose and in masses with several other shells in a red limestone.

Fig. 5. *Trigonia Smeeii.* Transversely much elongated, posteriorly truncated, convex, concentrically ribbed; the posterior surface distinguished by an obscure ridge, and furnished with twice as many ribs as the other part; ribs obtuse, seldom interrupted; beaks near the anterior extremity, which is rounded. Length 2 inches 5 lines, width 4 inches. The figure is reduced to $\frac{2}{3}$rds the natural size.

Fig. 6, 6 *a.* *Tornatella striata.* Ovate, pointed, transversely punctato-striated; one obscure plait on the columella. Height $2\frac{1}{2}$ lines, diameter $1\frac{1}{2}$ line.

Much resembling *Phasianella striata* (Fitton, in vol. iv. Pl. XVIII., f. 15.), but the apparent plait on the columella, if it be not the effect of fracture, distinguishes it. Fig. 6 *a.* is magnified.

Fig. 7. *Terebratula microrhyncha.* Subtetrahedral, rounded, plaited, lower valve nearly flat, plaits angular, 28 or 30, of which about 9 are raised in the front; beak of the lower valve very small, its aperture inclined inwards, and its sides smooth and sunk. Length 2 inches, width $1\frac{3}{4}$ inch, depth of the valves united $1\frac{1}{2}$ inch.

A large species, distinguished from *T. nobilis* (Grant, Pl. XXII., f. 14.) by the greater number of plaits.

Fig. 8. *Ammonites Maya.* Discoid, convex with a rounded front, umbilicated, radiated; umbilicus conical, smooth within; radii rather numerous, slightly elevated 2-, 3- or 4-partite, bent over the edge of the umbilicus; aperture rounded-sagittate with truncated angles. Diameter $7\frac{3}{4}$ inches, width of the aperture $3\frac{1}{2}$ inches, its length 4 inches.

This is an intermediate species between *A. formosus* (Grant, Pl. XXIII. f. 7.), and *A. Herveyi* (M. C.), a variety of which also occurs with this. Its sides are flatter than in the *A. Herveyi*, although the front is round, and the ribs less raised.

Fig. 9. *Ammonites calvus.* Discoid; inner whorls two thirds exposed, nearly crossed by rounded ribs, and plaited over their fronts; outer whorls crossed by prominent rounded ribs, their front rounded, plain; aperture oval, impressed by the preceding

whorl. Diameter 7 inches, width of the aperture $1\frac{1}{2}$ inch, its length $2\frac{1}{4}$ inches. A larger specimen measures $9\frac{1}{2}$ inches across, and is less plaited and ribbed. The figure is drawn $\frac{1}{3}$rd of the natural size.

Very near *A. decipiens* (M. C.), but the whorls increase more rapidly and envelope each other more.

Fig. 10. *Ammonites Pottingerii.* Discoid, thick, costated; inner whorls exposed; front nearly flat; ribs sharp, prominent, split into two or three over the front; aperture transversely obovate. Diameter $4\frac{1}{2}$ inches, width of the aperture 1 inch 8 lines, its length 1 inch 2 lines.

A very distinct species, cast in coarse limestone, replete with large grains of quartz.

Fig. 11. *Ammonites fissus.* Discoid, costated; whorls rapidly increasing, the inner exposed. Costæ large, obtuse, either forked or simple, with an intermediate short rib passing over the front, which is convex and prominent; aperture ovate. Diameter $4\frac{1}{4}$ inches, width of the aperture 1 inch 5 lines, its length $1\frac{1}{2}$ inch; the figure is reduced to one half.

Fig. 12. *Ammonites torquatus.* Discoid, costated; inner whorls exposed; costæ numerous, generally split into two as they pass over the rounded front, sometimes single, and (in large specimens) occasionally trifid; inner edges of the whorls incurved; aperture orbicular; whorls about five. Diameter $2\frac{3}{4}$ inches, width of aperture 1 inch, its length the same.

In large specimens are indications of a thickened edge having been formed to the aperture at various periods of growth. It is like *A. annulatus vulgaris* (Zieten, Pl. IX. f. 1.), and also *A. colubrinus major* (*Id.* Pl. IX. f. 3.), but distinguished by the incurved inner margin from both, as well as from a similar species found in the Himalaya Mountains.

Fig. 13. *Ammonites Fornix.* Discoid, compressed, (when young, keeled,) undulated; inner whorls $\frac{1}{3}$rd exposed, their exposed parts smooth; margin convex, smooth, with a row of minute tubercles on each side, and a slender keel, which are lost in the external whorls; undulations bent back in the middle of the sides, divided towards the margin; aperture sagittate, elliptical. Diameter 2 inches, width of aperture 7 lines, its length 1 inch 2 lines.

Fig. 14 *a.* to *f. Nummularia exponens.* Very flat, thin, granulated, whorls few; septa rather distant, visible through the shell; chambers twice as long as deep. Diameter of the shell frequently more than an inch. *Fig.* 14 *f.* is a magnified section.

When young, this *Nummulite* is lenticular; when old, it is concave in the centre.

PLATES AND MAPS

IN ILLUSTRATION

OF

VOLUME V.

SECOND SERIES,

OF

THE TRANSACTIONS

OF

THE GEOLOGICAL SOCIETY

OF LONDON.

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SOLD AT THE APARTMENTS OF THE GEOLOGICAL SOCIETY,
SOMERSET HOUSE.

1840.

COALBROOK DALE.

New Red System

Carboniferous System
- Upper
- Coal formation
- Lower
- Coal

Carboniferous Limestone

Old Red System

Silurian System
- Upper Silurian Rocks — Upper, Middle, Lower — Ludlow Rocks
- Limestone, Shale — Wenlock Rocks
- Lower Silurian Rocks — Caradoc Sandstone

Rocks of igneous origin

Line of Fault

Probable line of fault

Anticlinal line

dip

Probable Range of Trap

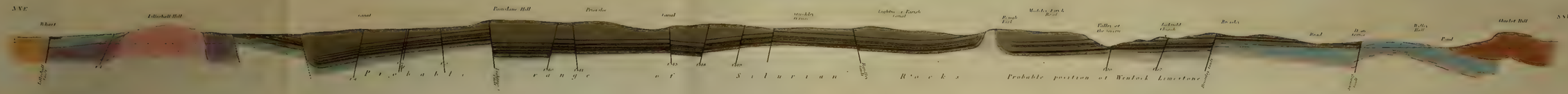
Wrekin Fault

The Wrekin Hill

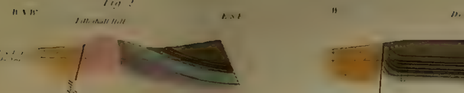
Scale 1 Inch = 1 Mile

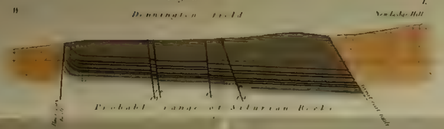
COALBROOK DALE

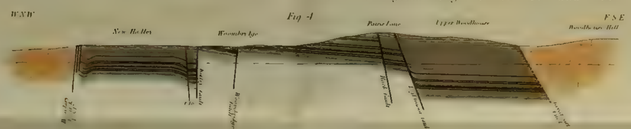
Fig 1 Longitudinal Section

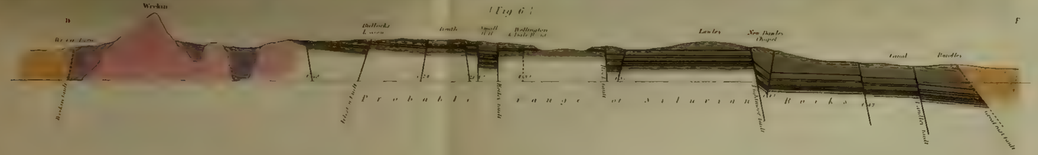


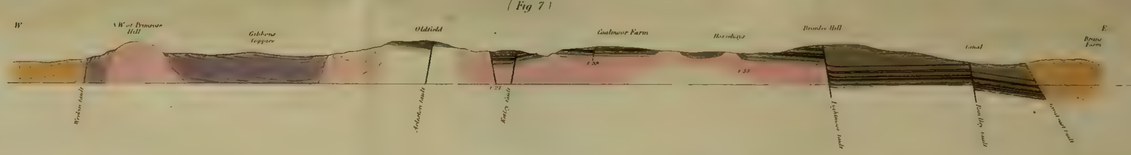
Transverse from Fig 2 to 12 and 14

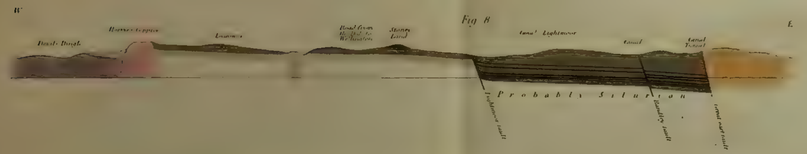


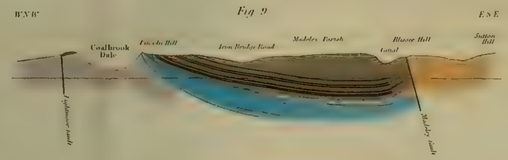












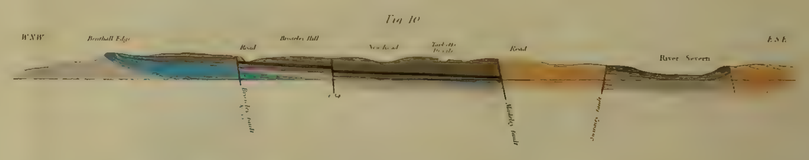


Fig 13 Diagonal Section

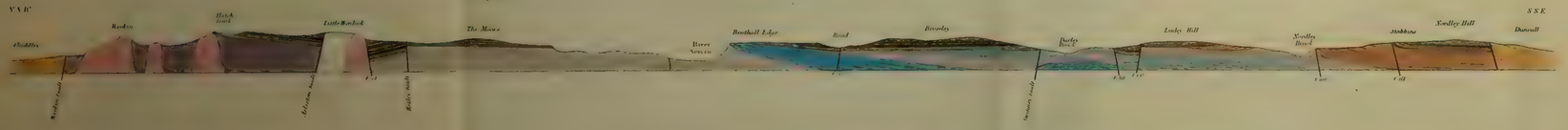
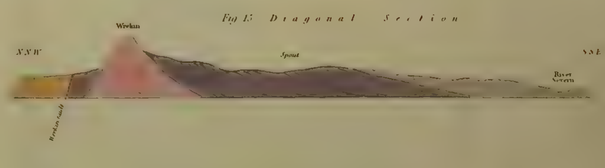


Fig 16 Transverse Section

Fig 14 Diagonal Section

Fig 15 Diagonal Section



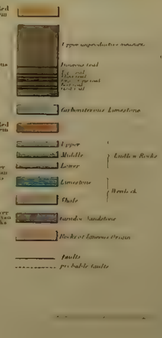
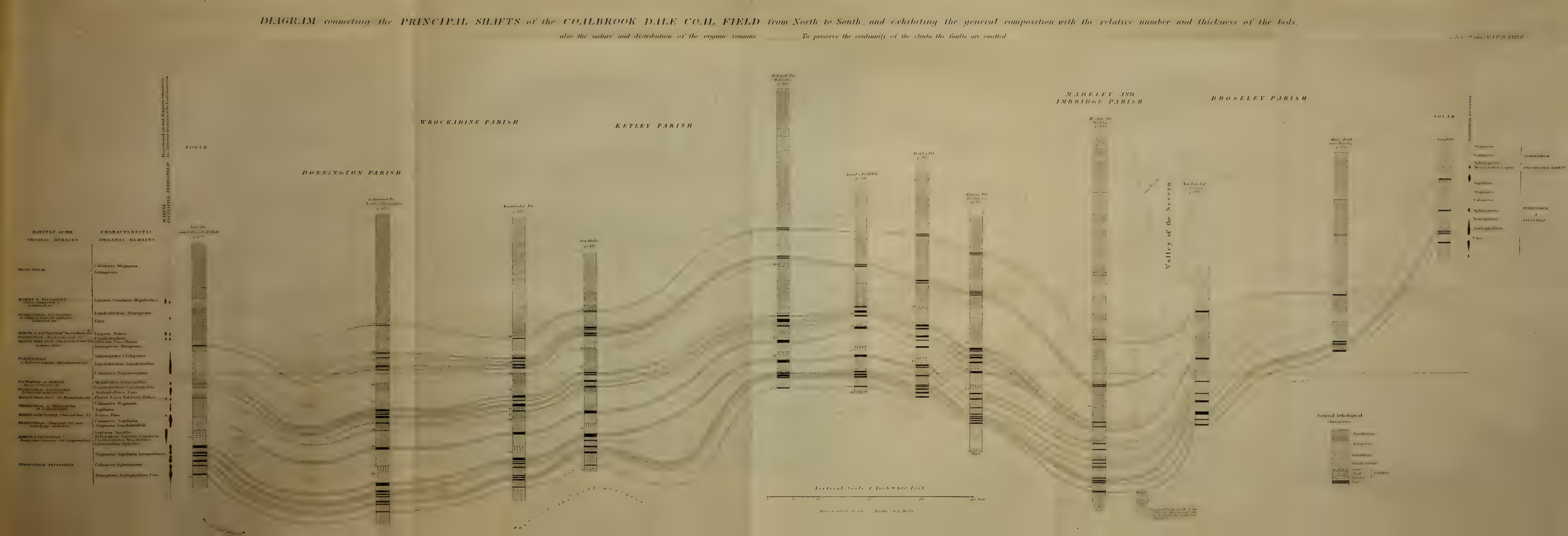


DIAGRAM *connecting the* PRINCIPAL SHAFTS *of the* COALBROOK DALE COAL FIELD *from North to South, and exhibiting the general composition with the relative number and thickness of the beds.*

also the nature and distribution of the organic remains *To preserve the continuity of the strata the faults are omitted*



COALBROOKE DALE COALFIELD.

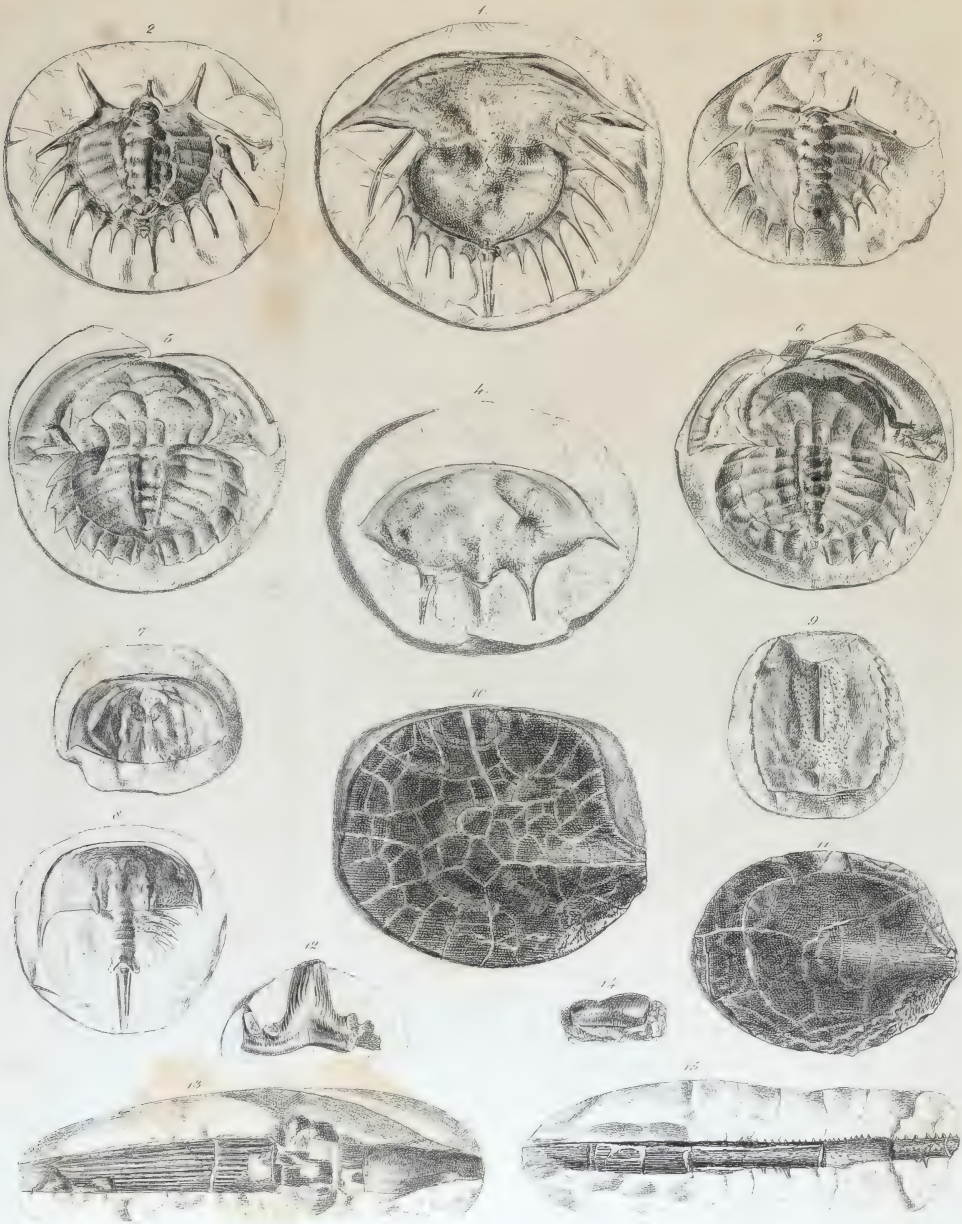
Natural size 2 to 10, 12 & 12a. Half Nat. size 1. Magnified Portion ... a to c, 8a & 8b

COALBROOKE DALE COALFIELD.

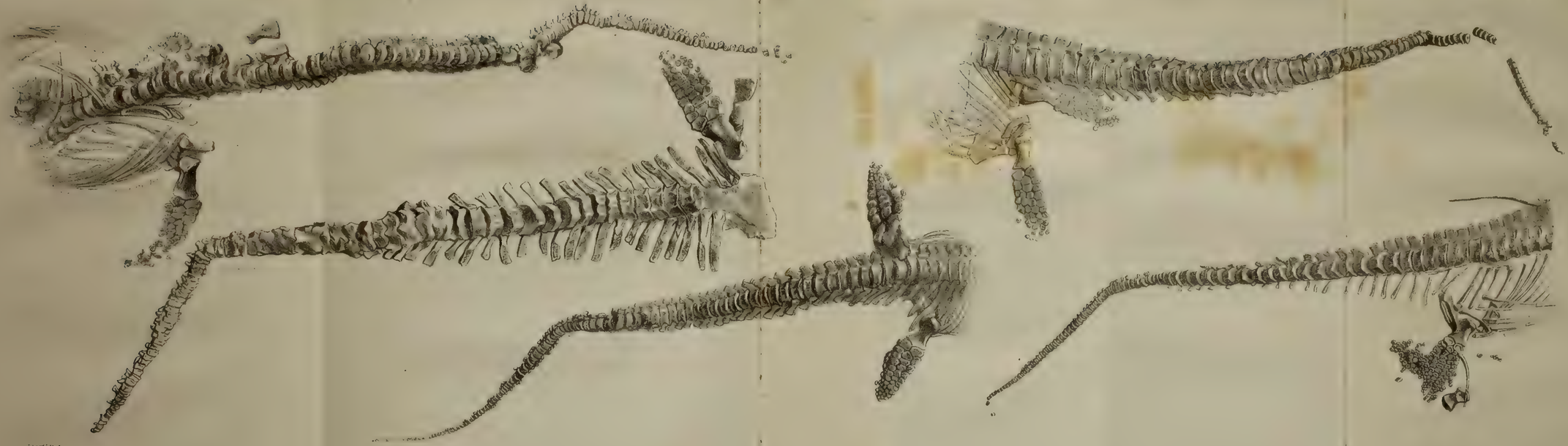
COALBROOKE DALE COALFIELD.

All the Figures are of the Natural size except 2a & 2b which are magnified

COALBROOKE DALE COALFIELD



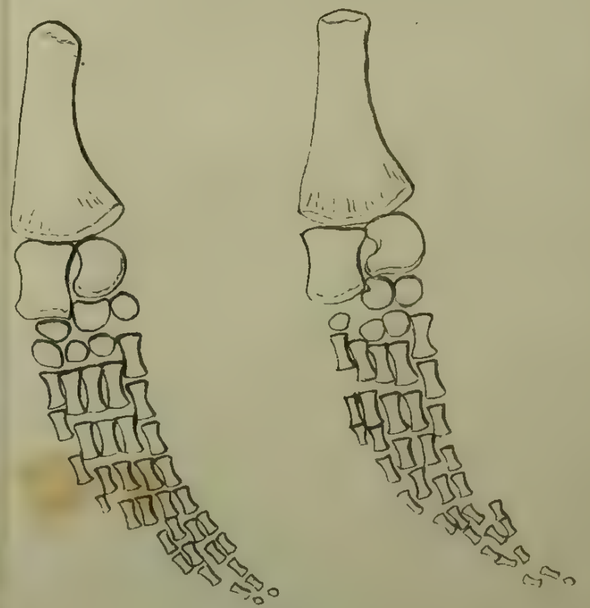
All the Figures are of the natural size



Dissecated Tails of Ichthyosauri

Plesiosaurus macrocephalus.

Plesiosaurus dolichodeirus



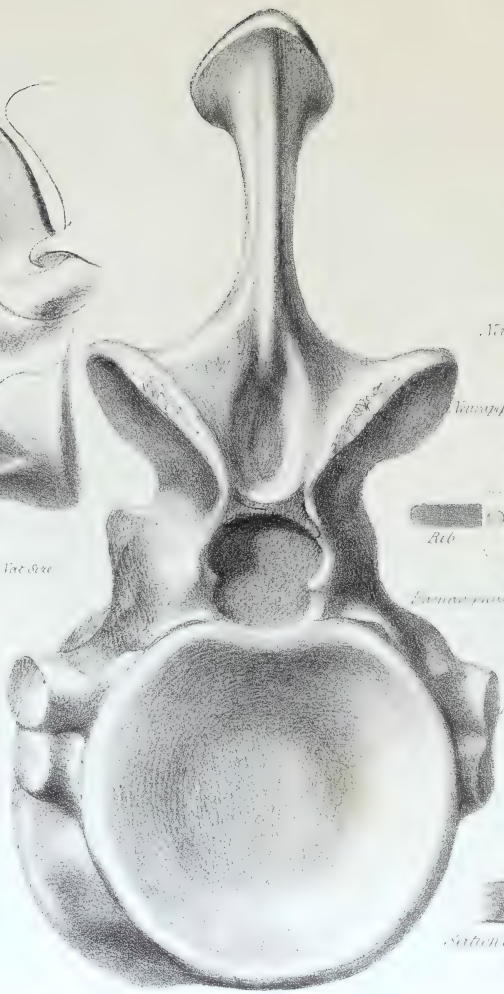
Plesiosaurus Hawkinsii

C. Scharf del et lithog

Fig 5

Fig 4

Plesiosaurus Hawkinsii Nat Size



Plesiosaurus arcuatus Nat Size

Fig 1 p 518

Fig 2

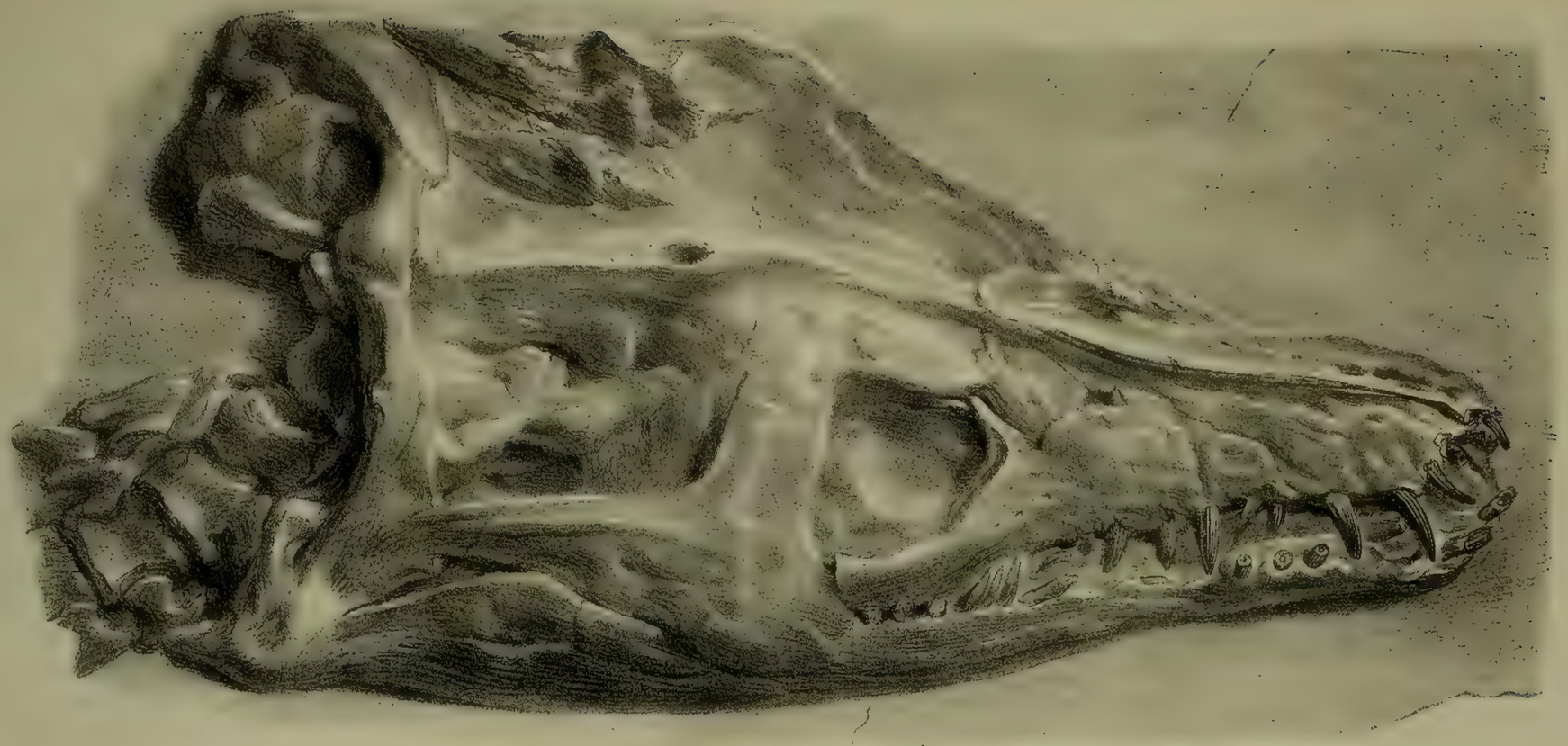
Caudal Vertebra
Python p 518

Fig 3

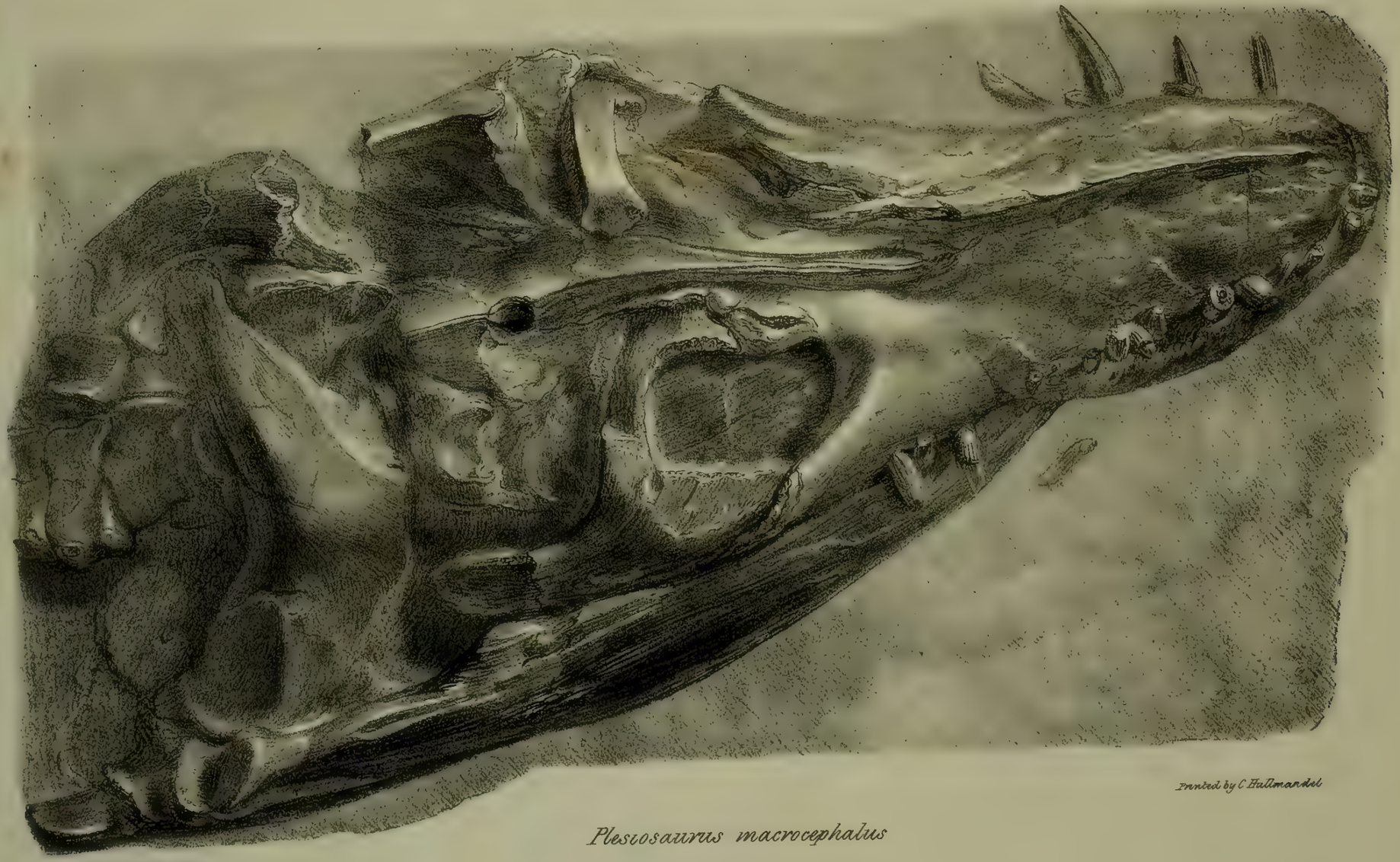
Cervical Vertebra
Python p 518

Fig 6

Section of Hæmal Canal of Vertebra
of Plesiosaurus



Plesiosaurus Hawkinsii



Printed by C Hullmandel

Plesiosaurus macrocephalus

Lithog from Nature by G Scharf

Geol. Trans. 2d Series Vol. V Pl. XLVI
Section 1.
Section 2.
South-east Portion
of the
GREAT BASALTIC DISTRICT
of
INDIA
to illustrate Mr. Malcolmson's memoir
p. 357.
Diamond Sandstone
Argillaceous Limestone
Granite & Gneiss
Mica, Chlorite & Hornblende Slates
Basalt
Laterite
Alluvium
NAGPOOR
HYDERABAD
BEEJAPOOR
MOODGUL
KURNOOL
BELLARY
GOOTYDROOG
CUDDAPAH
NELLORE
GUNTOOR
MASULIPATAM
ELLORE
AURUNGABAD
Ellora
CHITTLEDROOG
Madras

SOUTHERN INDIA.
(See M.Malcolmson's Memoir p.557.)

Fig.1 Between Akserai and Kelleli p 587

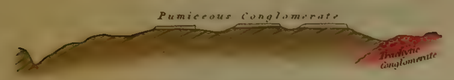
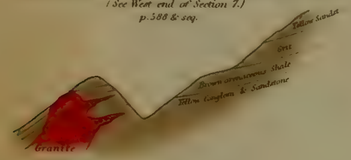


Fig. 2 Section extending N.N.W. from Kodj hissar p 588 & seq.

Fig. 3. Enlarged Section of Granite veins in Sandstone.
(See West end of Section 7.)
p 588 & seq.



PART OF ASIA MINOR
between the Salt Lake of Kodj-hissar
and Cæsarea of Cappadocia
to illustrate Mr Hamilton's Memoir
p. 583.

Fig. 4 p 584
Section from Hassán Dagh to the Hills north of the plain of Akserai

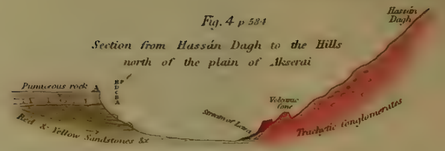
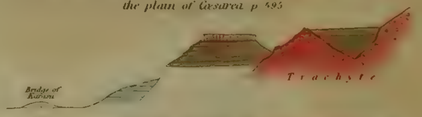


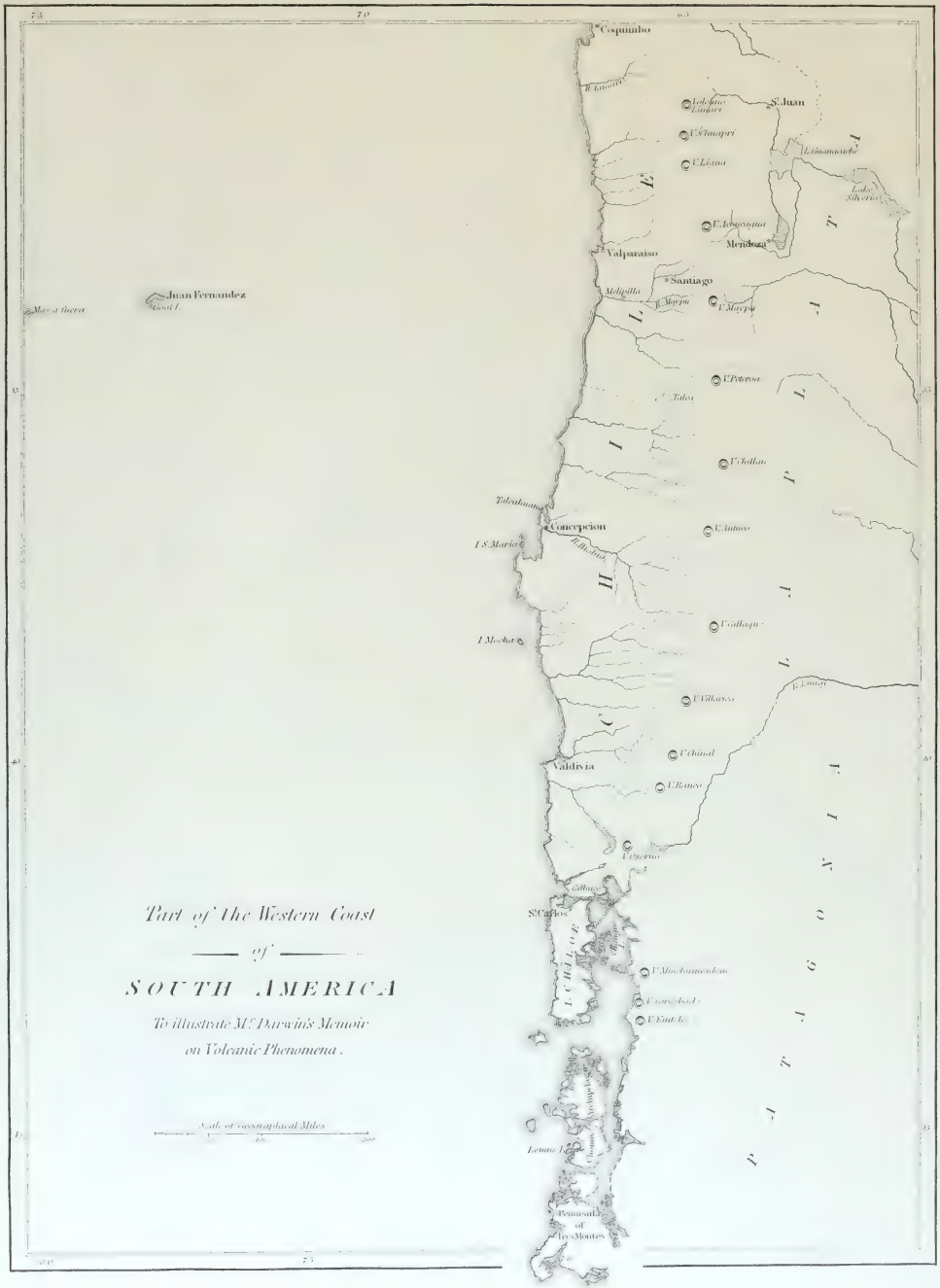
Fig. 5 Conical Hills near Uch hissar p 592

Fig. 6. Section of the Hills where the Karasú or Melas flows out of the plain of Cæsarea p 595



Authors line of route from Kodj-hissar to Cæsarea.

Fig. 7. p. 588 & Seq


Coquimbo
R. Limari
Volcano Limari
S.t Juan
V. Chuapri
V. Ligua
L. Guanacache
Lake Silverio
V. Aconcagua
Mendoza
Valparaiso
Santiago
Melipilla
R. Maypu
V. Maypu
Juan Fernandez
Goat I.
Mas a fuera
V. Peteroa
Talca
V. Chillan
Talcahuano
Concepcion
I. S. Maria
R. Biobio
V. Antuco
V. Gallaqui
I. Mocha
R. Limay
V. Villarica
V. Chinal
Valdivia
V. Ranco
V. Osorno
Gallaco
S.t Carlos
I. CHILOE
V. Minchinmadom
V. Corcobado
V. Yantele
Archipelago
Lemus I.
Chonos
Peninsula of Tres Montes
CHILE
LA PLATA
PATAGONIA
Part of the Western Coast
of
SOUTH AMERICA
To illustrate Mr. Darwin's Memoir
on Volcanic Phenomena.
Scale of Geographical Miles
100
200

GEOLOGICAL MAP
OF
DEVONSHIRE AND CORNWALL
to illustrate the Memoir by
the Rev.d A. Sedgwick & R. I. Murchison, Esq.r
The Colours of the formations are in accordance with the classification proposed by the authors in the Memoir. — The lines of demarcation are with the consent of M.r De la Beche copied from his Index Map of that region.
Scale of Miles
5
10
15
20
BRISTOL CHANNEL
SOMERSET
DEVONSHIRE
CORNWALL
DARTMOOR FOREST
Lundy Island
BIDEFORD BAY
HARTLAND P.T
BARNSTAPLE
BIDEFORD
TORRINGTON
OAKHAMPTON
EXETER
LAUNCESTON
TAVISTOCK
BODMIN
TRURO
PENZANCE
LANDS END
LIZARD
ST. IVES
FALMOUTH
HELSTON
Teignmouth
Dawlish
TOR BAY
START POINT
BOLT H.D
SIDMOUTH
COLYTON
TAUNTON
WELLINGTON
North Molton
South Molton
Chumleigh
Crediton
Tiverton
Cullumpton
Kilkhampton
Holsworthy
Stratton
Tintagel
Padstow
Trevose H.d
Lostwithiel
St. Austell
Grampound
Looe
Saltash
Plymouth
Kingsbridge
Dartmouth
Totnes
Ashburton
Newton Bushell
Moreton Hampstead
Callington
Liskeard
Linton
Ilfracombe
Morte P.t
Dunster
Minehead
New red Sandstone
Carboniferous System
Culm measures Black Limestone &c
Devonian System
old red Sandstone
Chlorite & Mica Slates
(Metamorphic Rocks)
Granite
Serpentine
Elvan & Trap Dykes

SECTIONS TO ILLUSTRATE REVp A. SEDGWICK AND Mr MURCHISON'S MEMOIR ON DE

Fig. 1. From the Foreland near Linton to Dartmoor.

Curvilinear Section Line AB. Map.

Fig. 2. From Marwood to Dartmoor NNE. to S.S.W.

Line CD. Map.

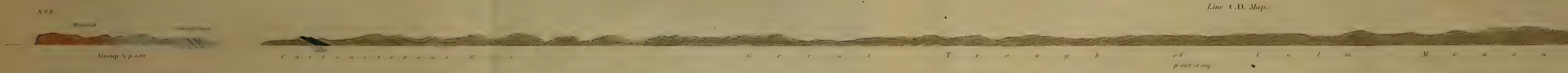


Fig 3.

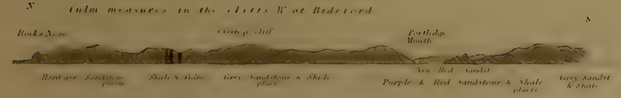


Fig 4. From the southern slopes of Exmoor to the Culm Measures N. to S.

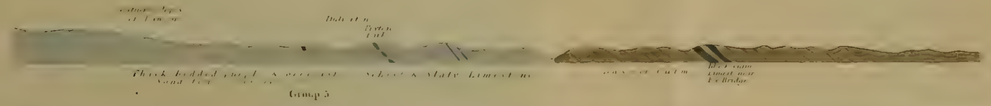


Fig. 6. From Start Point to Berry Head S. to N.

Fig 7. From Heath Field N. of Tavistock to Thistle Brook

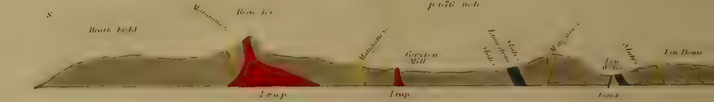
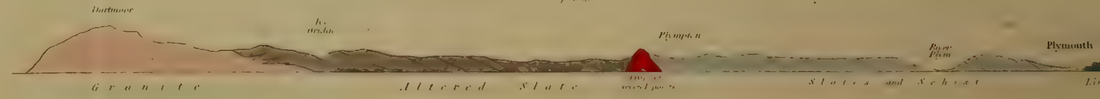


Fig 9. From Dartmouth to Plymouth Limestone.



Forcland near Linton to Dartmoor.

Curvilinear Section Line AB. Map.

rom Marwood to Dartmoor N.N.E. to S.S.W.

Line CD. Map.

Group 5

Fig. 5. From Plymouth to Bolt Head N. to S.

Fig 7. From Heath Field N. of Tavistock to Thistle Brook Lower Culm Measures

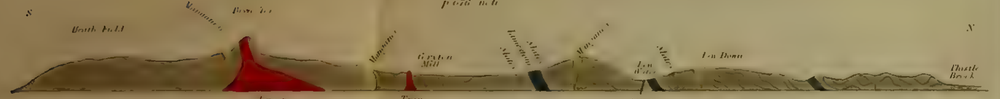
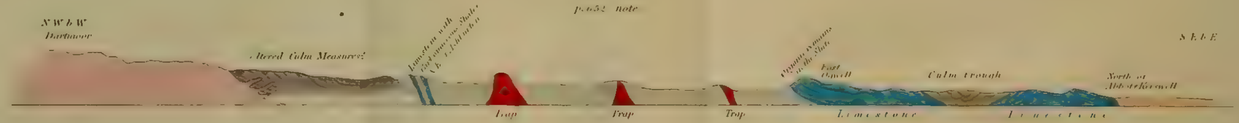
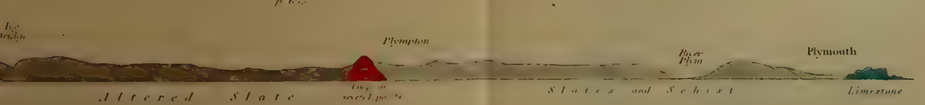


Fig. 8. From Dartmoor to Abbots Kerswell.



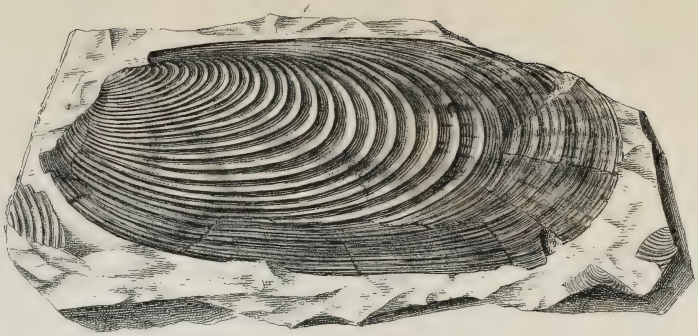
a. 9 From Dartmouth to Plymouth Limestone.



Explanation of Colours.

The Carboniferous System Culm Measures &c is represented in all the Sections by the same blue tint as that used in the Map but the Devonian System Old Red Sandstone which in the Map is represented by a reddish brown is in the Sections divided into groups each distinguished by a separate colour.

DEVONSHIRE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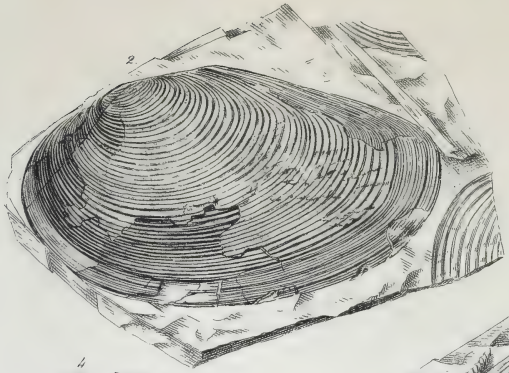
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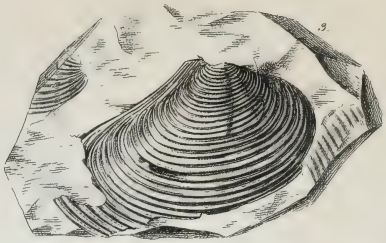
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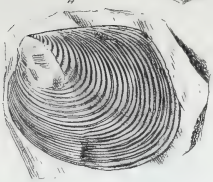
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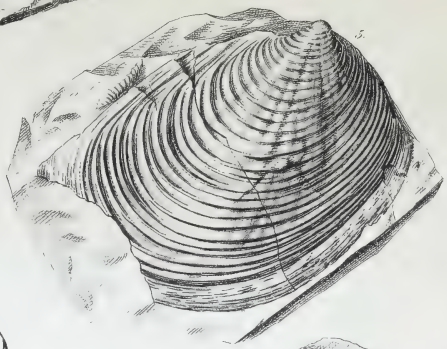
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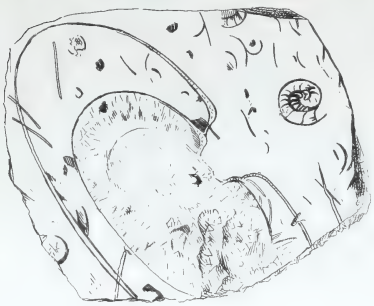
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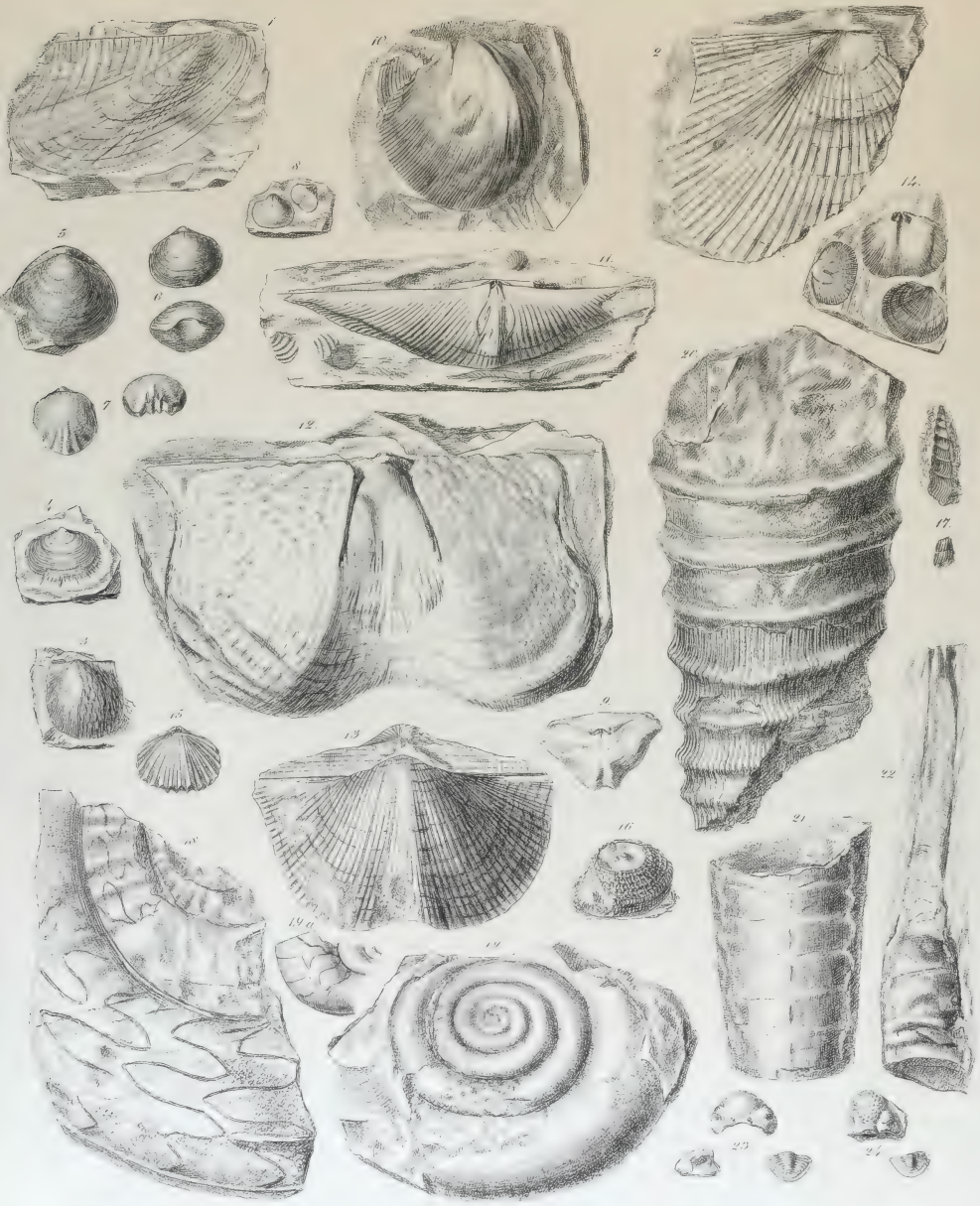
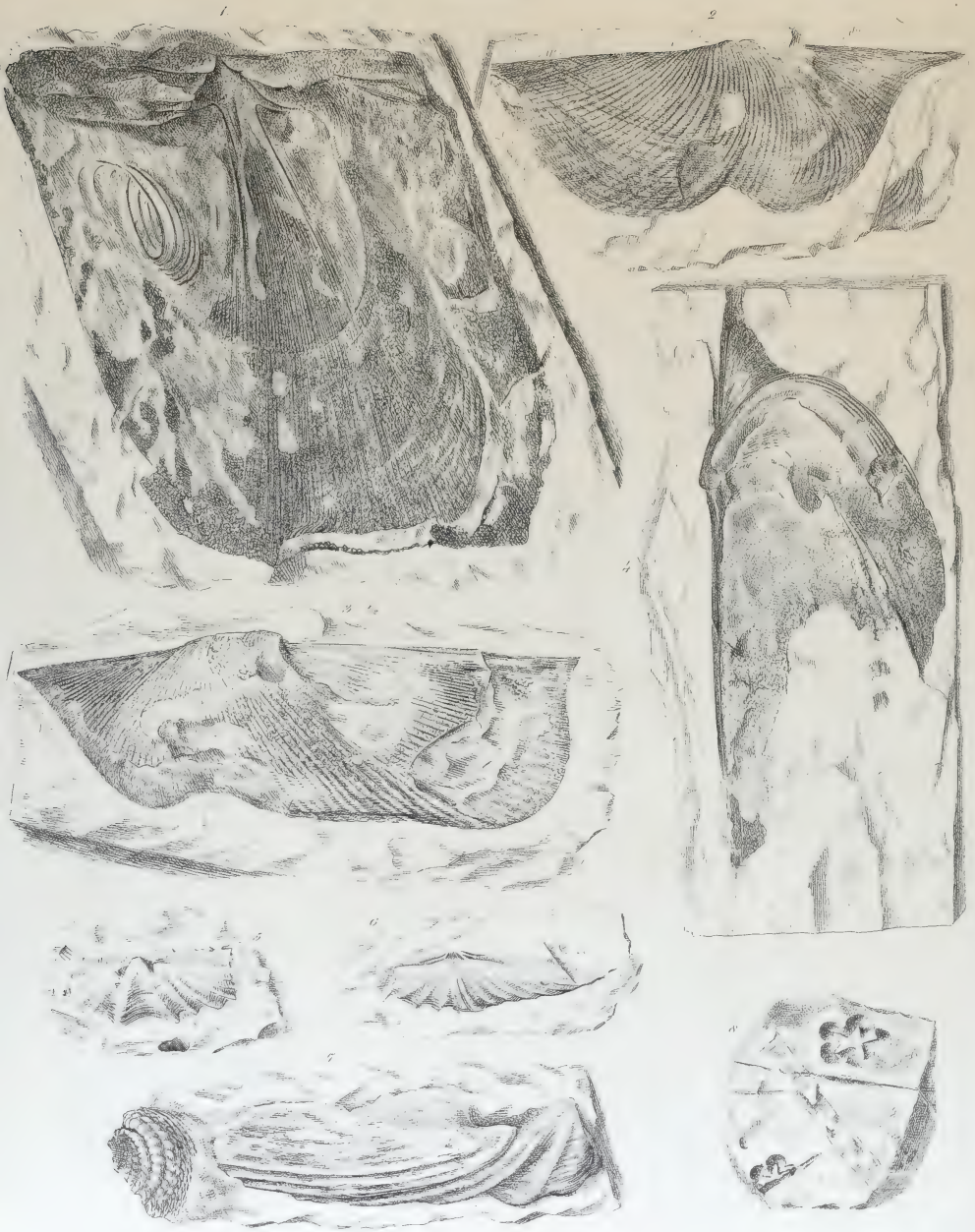
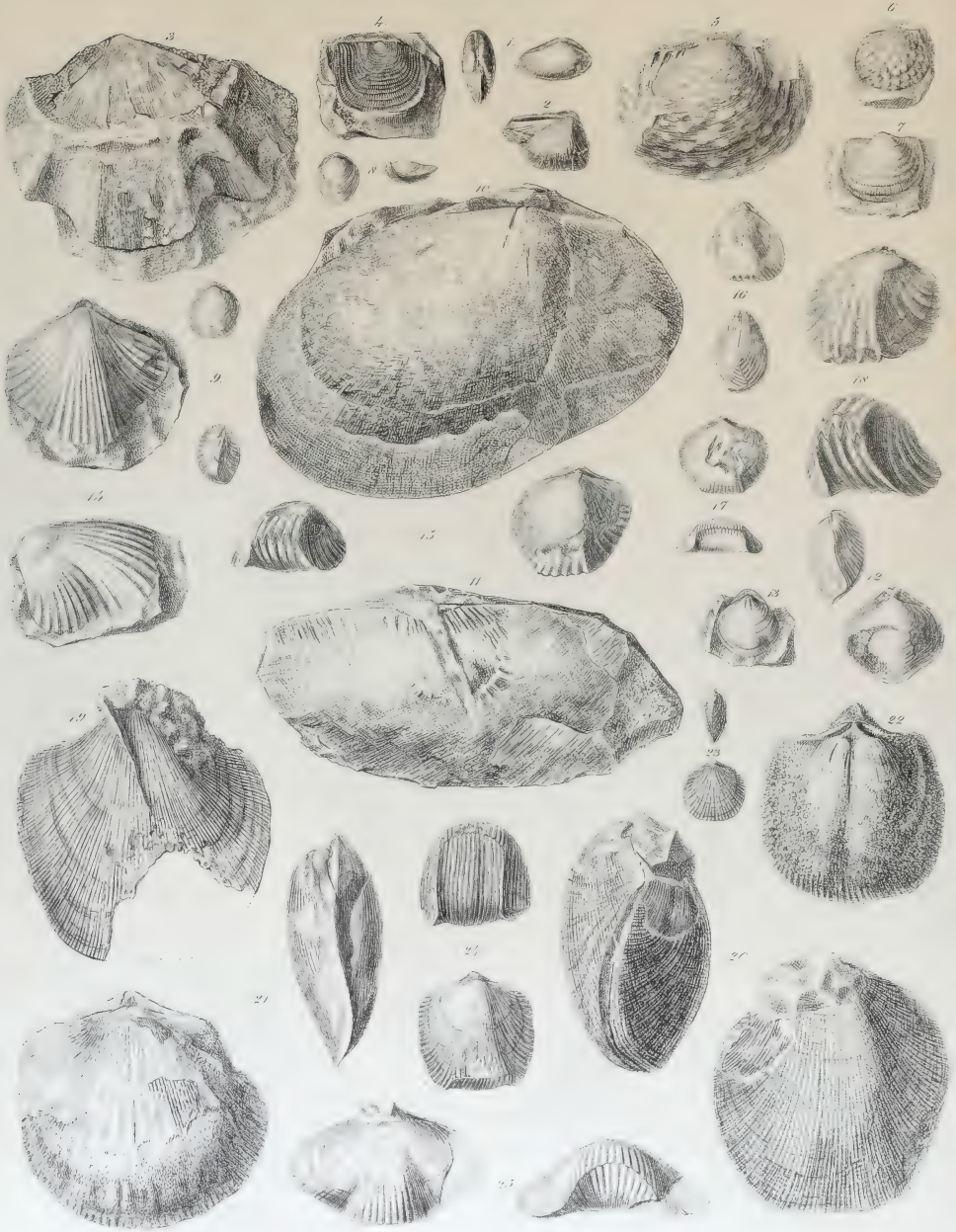
CORNWALL



CORNWALL.



DEVONSHIRE



DEVONSHIRE.

Fig. 2.
Fig. 4
1a
3a
4a
4b
Fig. 1
Fig. 3
4c
Fig. 7
7a
3b
4f
4d
4e
Fig. 6
Fig. 5
5b
Fig. 8
5a
Fig. 10
5c
5d
6a
6b
6d
Fig. 9
10b
11b
Fig. 11
11a

Fig. 1

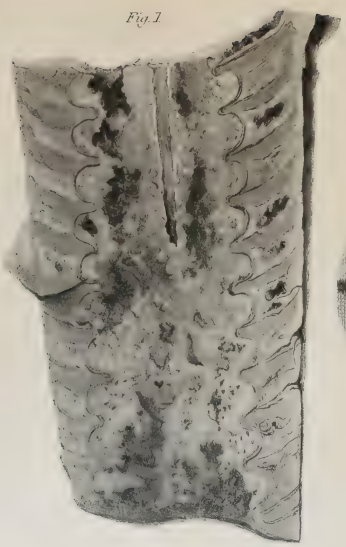


Fig. 5

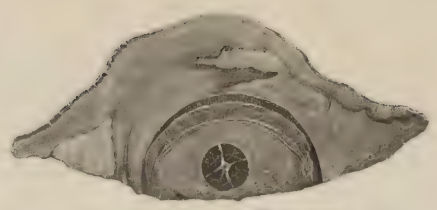


Fig. 6

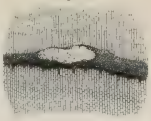


Fig. 4

1/3 of natural size

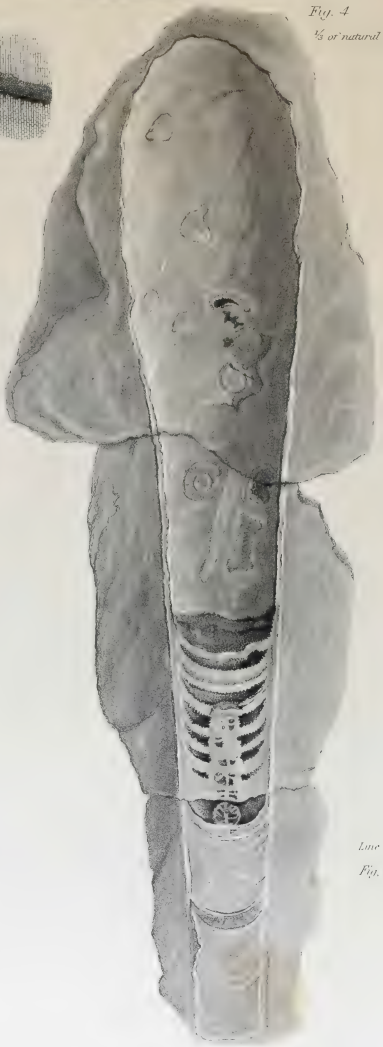


Fig. 3

Fig. 2

Line of section

Fig. 5

Zetter Sculp.

Fig. 1

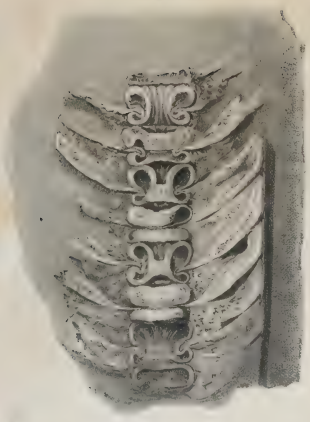


Fig. 2

Fig. 3

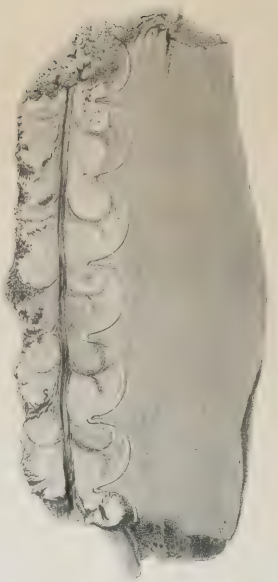


Fig. 4

Fig. 5

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